1071

ESTIMATION OF ADDITIONAL ABATEMENT COSTS FOR THE PROPOSED REVISIONS TO REGULATION 308

JULY 1990

Ontario
Environment
Environnement
Jim Bradley, Minister/ministre

ISBN 0-7729-7290-7

ESTIMATION OF ADDITIONAL ABATEMENT COSTS FOR THE PROPOSED REVISIONS TO REGULATION 308

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Report Prepared for:
Policy and Planning Branch
Ontario Ministry of the Environment

JULY 1990

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PIBS 1071
log 90-1104-004

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8.1 Scenario Abatement Costs

EXECUTIVE SUMMARY

1.0 INTRODUCTION

The Ministry of the Environment (MOE) has proposed that Regulation 308 (Reg. 308) be revised so that the existing point of impingement standards are replaced with new ambient air standards and technology-based emission limits. The proposed revisions are expected to result in greater control of emissions and increased control costs.

The objective of this study is to estimate the additional abatement costs necessary to ensure compliance with the proposed revisions to Reg. 308 for each major industrial sector, for waste disposal companies and for municipalities.

A number of tasks were performed in the preparation of the estimates of additional abatement costs. Background information concerning proposed changes to Reg. 308 and the contaminants and scenarios considered in the subsequent cost estimates are discussed in Chapter 2. Air pollution control technology for particulate matter removal and gas and vapour control equipment are described in Chapters 3 and 4, respectively. These control technologies are later applied to various processes in industry so that the cost estimates of controlling emissions could be determined. Specific sectors and processes within broader Standard Industrial Classification (SIC) categories are examined in Chapter 5. Existing controls, emissions, production and number of employees are also identified. Estimates of current emission factors and those needed to achieve successive levels of additional control under the proposed revisions are given in Chapter 6. Existing and proposed control equipment are also identified. Using information discussed in Chapters 2 to 6, Chapter 7 provides estimates, by SIC categories, of the capital and operating costs for the alternative abatement scenarios. The results of the study are summarized in Chapter 8.

2.0 BACKGROUND INFORMATION AND ASSUMPTIONS

Proposed Revisions

The most significant change in Reg. 308 is the replacement of existing point of impingement standards with a new approach of controlling air emissions at source before they are released into the atmosphere by enacting three stringent levels of emission limits.

A proposed three level control system has been followed in this study. Level 1 has the strictest controls and would deal with high hazard contaminants. Level 1 corresponds to the emission control strategy developed in the U.S. known as LAER or Lowest Achievable Emission Rate. Level 2 has moderately strict controls for medium hazard contaminants which would require reduction by the Best Available Control Technology which is Economically Achievable (BACT-EA). Level 3 controls are the least stringent and would apply to low hazard contaminants which can be controlled by technology generally demonstrated as acceptable. Level 3 corresponds to the control strategy referred to as New Source Performance Standards, or NSPS.

Contaminants Considered

Based on the MOE paper on proposed amendments to the Air Pollution General Regulation 308 (MOE, 1987) and on discussions between the MOE and the study group, a set of 93 contaminants was selected for consideration in this study. They were categorized further into the following groups:

- volatile organic compounds
    - chlorinated
    - aliphatics
    - aromatics
    - esters, ethers, aldehydes, ketones
    - mercaptans
    - others
- particulates associated
    - organic
    - metals
- other particulate matter
- semi volatile organics
- pesticides
- corrosives
    - acids
    - bases
- others

Assumptions

One hundred percent compliance with existing Reg. 308 and the proposed revisions to Reg. 308 has been assumed for the purposes of this study. It is recognized that this level of compliance will only be approached with a greatly enhanced enforcement and monitoring effort by MOE.

3.0 AIR POLLUTION CONTROL EQUIPMENT FOR PARTICULATE CONTROL

Particulate control technology was evaluated in the following five categories:

- Inertial Separators
- Wet Collection Devices
- Fabric Filters (Baghouses)
- Electrostatic Precipitators
- Others (Precleaners)

A summary of each of these control devices is found in Table S.1 and includes primary use, collection efficiency, advantages and disadvantages for each category.

4.0 GAS AND VAPOUR CONTROL EQUIPMENT

Gas and Vapour control technology was evaluated in the following five categories:

- Absorption
- Adsorption
- Chemical Reaction
- Incinerator
- Condensation

A summary of these categories is found in Table S.2 and includes the principle behind each technology, important factors for each and examples of how the control is achieved.

5.0 INDUSTRY SECTORS

The sectors evaluated in this study were selected by the MOE and are listed below:

- open pit mining
- food industry
- pulp and paper and allied products
- iron and steel industry
- foundries
- non-ferrous smelters and refineries
- automotive industry
- inorganic chemical manufacturing
- petroleum refineries
- asphalt paving
- petrochemical products manufacturing
- electrical power generation
- waste disposal facilities
- municipal incinerators

These are further separated into four digit Standard Industrial Classification (SIC) categories and individual processes. Based on discussions with the MOE, availability of data, and on combining of similar categories, a total of 43 SIC categories and 316 processes were selected for this report.

Methodology

This study collected quantitative data (mostly from 1986) on the following items:

- Industrial, commercial and municipal processes in Ontario falling within the SIC categories identified above.
    - Production and capacity by process
    - Employment by process
    - Process emissions and emission factors
    - Existing emission controls and controls required to reduce air emissions to levels indicated in the proposed revisions to Reg. 308.
- Capital and operating costs of control for existing equipment and for equipment likely to be necessary to achieve levels of air emissions indicated in the proposed revisions.

The gathered data were used to characterize each industry or group of industries, and annual emission estimates were made from available data using emission factors. Emission factors, which were used when no site-specific information was available, are based on average emission quantities developed from measured sources. They are expressed in terms of emitted quantities or emission rates proportioned to some factor representative of the rate of operation of the source (e.g. (gm/sec)/(tonnes feed/sec)). The general characteristics and emissions generated in each sector are presented in Tables A and B of Chapter 5.

6.0 EMISSION FACTORS AND POTENTIAL CONTROL SYSTEMS

Assessments were made of the industries studied, and the control technologies needed to enable their processes to meet the three levels of control required in the proposed revisions to Reg. 308 were identified. The emissions which would then be released from the various sources were quantified in the form of emission factors to be applied to the sources.

The major sources of information for the emission factors were: U.S. EPA BACT/LAER clearinghouse publications; Best Available Control Technology reports by South Coast Air Quality Management District; and AP-42 Compilation of Emission Factors. Many of the factors were estimated from reported results on recently installed equipment.

The emission rates required to satisfy alternative abatement levels and the control equipment recommended for each are presented in Tables A and B of Chapter 6.

7.0 ALTERNATIVE ABATEMENT SCENARIOS: INDUSTRY COSTS AND EMISSIONS

Five abatement scenarios are considered. They include Scenario A which requires that control Level 2 (BACT-EA) is applied to most contaminant groups, a more stringent Scenario B under which control Level 1 (LAER) is applied to most contaminant groups and Scenario C for which a less stringent level of control, Level 3 (NSPS), is applied to most contaminant groups. In addition, two other scenarios are examined: a two-tiered Scenario D, and a phased-in Scenario E which is identical to Scenario A, but implemented more slowly. The contaminant group and degree of control by scenario are shown in Table 2.2.

Capital and annual operating cost estimates for abatement Levels 3,2, and 1 have been prepared by process within each sector. These costs have then been used to prepare capital and annual operating costs for the five abatement scenarios. Finally, the annual emissions resulting from implementing the five scenarios have been estimated. The costs by level of control and scenario, and the emissions released as a consequence are presented in Tables A, B, C and D of Chapter 7.

8.0 SUMMARY

The estimated capital and operating costs by sector for each of the five scenarios are given in Table 8.1 and are in 1986 Canadian dollars. Scenario B, with predominantly Level 1 (LAER) control has the highest estimated aggregate capital cost, $4.7 billion, and the second highest operating cost, $454 million. Scenario C, with predominantly Level 3 (NSPS) control has the lowest capital cost, $2 billion, and second lowest operating cost, $365 million.

The degree of contaminant removal is in inverse proportion to the above costs with Scenario C providing the lowest emission reductions and Scenario B the highest.

Capital costs would be incurred over the duration of the phase-in period (i.e. up to five years for Scenarios A, B, C and D, and up to 25 years for Scenario E) and operating costs would be incurred anually. Scenarios A, D and E have identical aggregate capital costs that are about a third lower than for Scenario B but fifty percent higher than for the least stringent Scenario C. Aggregate operating costs are very similar for all scenarios and range from $421 million to $457 million annually.

TABLE S.1
AIR POLLUTION CONTROL EQUIPMENT

Equipment	Primary Use	Collection Efficiency	Advantages	Disadvantages
Inertial Separators Cyclone Separators Cyclone Separators	Collection of medium and coarse-sized particulate matter	Not high for particles <10 um	- Simple; low cost; low maintenance - Suitable for medium-sized particulates (15-40 um)	Unsuitable for fine dusts or metallurgical fumes
Wet Collection Devices	Wetting of contaminent particles for removal from gas stream	- 99% on particles $\geq$ 2 um - 10% on particles $\leq$ 0.1 um - efficiency dependent upon design; usually declines rapidly for particles between 1 and 10 um	- can handle high temperature or moisture-laden gases, corrosive gases, or aerosols - space requirements small - no secondary dust problem in disposing of collected dust - constant pressure drop	- disposal of waste water or its clarification may be difficult or expensive - possible corrosion and erosion problems - downstream mist eliminator often required
Fabric Filters (fabric bags housed in a "baghouse")	- removal of dust, fumes from gas stream when high collection efficiency of small particles is required - cloth serves as a supporting structure for dust mat	- 99.9% for particles $\leq$ 2 um	- very high efficiency of particle removal - very small particles are collected - material is collected dry - space requirements are not as large as for electrostatic precipitators	- gas temperatures cannot exceed '290o C - fabric may be susceptible to chemical attack - filter may be fouled by acid mist, condensation or tacky particles
Electrostatic Precipitators	- collection of particles from gas	often > 99%	- very small particles can be collected - dusts may be collected dry - pressure/temperature drops are small - can be used at high temperatures - can be used to collect acid and tar mists - corrosive materials can be collected with special construction - collection efficiency may be adjusted to suit application - very large gas flows can be handled - power requirements are low - low maintenance; few moving parts	- initial cost is high - not easily adapted to variable conditions - some materials cannot be collected - relatively large space requirement - gases cannot be removed - use of precleaner may be required - safety hazard due to high voltage voltage
Other (Settling Chambers, impingemant separators, panel filters)	- used principally as precleaners - used as final collectors where air contaminant is large or where grain-loading is small	- limited efficiency	- if gases contain many hard, coarse particles, a precleaner can reduce erosive wear on final, more expensive collector - if collected material has value, precleaner can collect it as useable form	

TABLE S.2

GAS AND VAPOUR CONTROL EQUIPMENT

Method	Principle	Important Factors	Examples
Absorption	. provide contact between the gas and liquid solvent to permit interphase diffusion of the materials . contact accomplished by dispersing gas in liquid or vice-versa	. rate of absorption dependent upon surface exposed, solubility of gas and degree of chemical reaction	Liquid Dispersion: packed towers, spray towers, spray chambers, venturi absorbers Gas Dispersion: spray towers, vessels with spraying equipment
Adsorption	. molecules of a fluid adhere to surface of a solid . gases, liquids or solids can be selectively captured or removed from airstreams with specific materials (adsorbents)	. adsorption can occur at all solid interfaces . high rate of adsorption if solid is very porous and has fine capillaries . large surface-to-volume ratio of adsorbents is important	activated carbon most suitable for removing organic vapours
Chemical Reaction	. control of NO_x, SO2, HCl during combustion and after emissions are released . combustion modifications reduce NO_x by: - limiting resident time in the primary flame zone - reducing flame temperature - reducing rapid mixing of fuel and secondary air		Combustion control of NO_x: low excess air staged combustion low NO_x burners flue gas recirculation Emission controls for NO_x: Selective Non-catalytic Reduction (uses ammonia addition at high temperature) Selective Catalytic Reduction (uses ammonia in presence of catalyst) Emission Controls for SO_2 and HCl: Chemical reaction in flue gas desulphurization systems of two types - wet & dry
Incineration	. use of afterburners to reduce or eliminate combustible aerosols, particulates, gases or vapour emissions		direct-fired afterburner - most commonly used for combustible aerosols, vapours, gases, odours (removal efficiency ~99%) catalytic afterburner usually for solvent & organic vapours as found in industrial operations using ovens (removal efficiency ~95%)
Condensation	. vapours can be condensed either by increasing pressure or extracting heat . air pollution control condensers operate usually in a cooling mode through removal of heat from vapour	. other applications require a condenser to be an integral part of other air pollution	Two types of condensers: surface: coolant does not contact vapours or condensate contact: coolant, vapours, condensate are mixed

1.0 INTRODUCTION

The Ministry of the Environment (MOE) has proposed that Regulation 308 (Reg. 308) be revised so that the existing point of impingement standards are replaced with new ambient air standards and technology-based emission limits. The proposed revisions are expected to result in greater control of emissions and increased control costs.

The objective of this study is to estimate the additional abatement costs of compliance with the proposed revisions for each major industrial sector, for waste disposal companies and for municipalities.

Scope of Work

A number of tasks were performed in preparing the estimates of additional abatement costs. In brief, they included:

- Identification of a comprehensive set of generic air pollution abatement technologies and the contaminants to which they are applicable.
- Identification of removal efficiencies for each generic technology in terms of ranges of percent reduction of contaminant release allowing for variations in work stream characteristics.
- From the literature and industry sources, preparation of a reasonable range of capital cost estimates and operating cost estimates for each of the generic technologies, allowing for economies of scale and input waste stream characteristics.
- In conjunction with Ministry staff, and for the purpose of this study, identification of Lowest Achievable Emission Rate (LAER), Best Available Control Technology which is Economically Achievable (BACT-EA) and New Source Performance Standards (NSPS) type technologies (see Section 2.1) and the additional costs of implementing them for each major industrial sector or category of contaminant.
- In collaboration with the Ministry and industry, estimation of plant or process-specific abatement costs for achieving controls similar to LAER, BACT-EA and

NSPS based on a selection of a number of representative plants (industrial, waste disposal and municipal).

- Revision of the estimated additional abatement costs in light of plant or process-specific cost estimates for several abatement options.
- Preparation of additional abatement cost estimates for five implementation scenarios and a planning horizon provided by the MOE.

While it is important to use the most accurate and detailed information available in studies of this type, it must be realized that in some instances the information needed is not always available. Furthermore, when information is available it may come from a number of sources which are often imprecise or which may not be in complete agreement with each other. Therefore, data and methods which were considered to be the best available, but not necessarily the most recent, were used to provide estimates of the costs of pollution control.

A variety of sources of information were consulted. These included many Trade and Manufacturing Associations, several companies, individuals at universities, the U.S. EPA and the California Air Resources Board, as well as the many reports listed in the references given at the end of each chapter and in the bibliography at the end of the report.

The results of the work are presented in the following chapters. Chapter 2 discusses background information concerning proposed changes to Reg. 308 and the contaminants and scenarios considered in the subsequent cost estimates, and also outlines assumptions made. Chapter 3 describes air pollution control technology for particulate matter removal, and Chapter 4 discusses gas and vapour control equipment. These control technologies were later applied to various processes in industry so that cost estimates of controlling emissions could be determined. Chapter 5 examines the specific sectors and processes within broader Standard Industrial Classification (S.I.C.) categories. Existing controls, emissions, production and employees are identified. Chapter 6 estimates current emission factors and those needed to achieve the successive levels of additional control proposed under the revised regulation. Existing and proposed control equipment is identified. Chapter 7 provides estimates by S.I.C. categories of the capital and operating costs for the alternative abatement scenarios as outlined previously in Chapter 2. Chapter 8 summarizes the results of the study.

Relevant references are included at the end of each chapter. Additional sources of information are in a bibliography at the end of the report.

2.0 BACKGROUND INFORMATION AND ASSUMPTIONS

2.1 Proposed Revisions

The most significant change in Reg. 308 is the new approach of controlling air emissions at source before they are released into the atmosphere. These emission limits are to be achieved in whatever way the emitters wish.

Contaminants are to be ranked based on their toxicity, persistence, bioaccumulative and transport characteristics (MOE, 1987). The proposed ranking would use a scoring system in which chemicals are evaluated in a number of categories, each representing an important hazard to health or property. Substances with high toxicity would be rated as high hazard contaminants. Emitters releasing these substances would be required to reduce them to the lowest achievable levels attained by the best removal technology known. Substances rated as medium or low hazard would be subject to controls appropriate to their classification.

A proposed three level control system has been followed in this study. Level 1 has the strictest controls and would deal with high hazard contaminants. Level 1 corresponds to the emission control strategy developed in the U.S. known as LAER or Lowest Achievable Emission Rate. Level 2 has moderately strict controls for medium hazard contaminants which would require reduction by the Best Available Control Technology which is Economically Achievable (BACT-EA). Level 3 controls are the least stringent and would apply to low hazard contaminants which can be controlled by technology generally demonstrated as acceptable. Level 3 corresponds to the control strategy referred to as New Source Performance Standards, or NSPS.

It is proposed that the new requirements come into effect immediately upon promulgation for all new sources. For the existing sources, the new requirements would be phased in over a five-year period for Level 1 and Level 2 contaminants. For the purpose of this study, variations in the phase-in period are considered in alternative abatement scenarios, discussed in Section 2.3.

2.2 Contaminants Considered

In the MOE discussion paper on proposed amendments to the Air Pollution General Regulation

308, a list of proposed ambient air standards for contaminants of concern to the MOE was included (MOE, 1987). Based on discussions between the MOE and the study group, a subset of 93 contaminants was selected for consideration in this study. They were categorized further into the following groups:

- volatile organic compounds
    - chlorinated
    - aliphatics
    - aromatics
    - esters, ethers, aldehydes, ketones
    - mercaptans
    - others
- particulates associated
    - organic
    - metals
- other particulate matter
- semi volatile organics
- pesticides
- corrosives
    - acids
    - bases
- others

In assessing a compound's volatility, the following U.S. EPA definitions were used (Lewis, 1986):

- volatile organic compounds:
    - compounds having a saturated vapour pressure at 25°C above 13.3 Pa (0.1 torr). (torr = 1/760 atmosphere or 1 mm of mercury)
- semi volatile organic compounds
    - compounds having a saturated vapour pressure at 25°C between 13.3 Pa (0.1 torr) and 13.3 uPa (10^{-7} torr)
- non volatile organic compounds

- compounds having a saturated vapour pressure at 25°C below 13.3 uPa (10^{-7} torr)

The non-organic compounds were grouped according to their chemical characteristics.

Table 2.1 shows the categories and the compounds placed in them.

2.3 Scenarios Considered

Five abatement scenarios are considered. They include Scenario A which requires that control Level 2 (BACT-EA) is applied to most contaminant groups, a more stringent Scenario B under which control Level 1 (LAER) is applied to most contaminant groups and Scenario C for which a less stringent level of control, Level 3 (NSPS), is applied to most contaminant groups. In addition, two other scenarios are examined: a two-tiered Scenario D, and a phased-in Scenario E which is identical to Scenario A but implemented more slowly. The contaminant group and degree of control by scenario are shown in Table 2.2.

Phasing in for existing and new facilities are given at the bottom of Table 2.2 and indicate that under the proposed adoption schedule (Case 1), contaminants of all levels of toxicity, Levels 1, 2, or 3, are to be controlled by 1994.

2.4 Other Regulations

For the purposes of this study, gaseous emissions from the INCO Sudbury Smelter Complex, the Falconbridge Smelter Complex and Ontario Hydro were not included nor costed because gaseous emissions are covered by separate regulations listed below.

O. Reg. 660/85 Inco Sudbury Smelter Complex - 1994
O. Reg. 661/85 Falconbridge Smelter Complex - 1994
O. Reg. 281/87 Ontario Hydro

Other emissions, such as particulates, from Inco, Falconbridge and Ontario Hydro are costed in this study.

2.5 Assumptions

Compliance

One hundred percent compliance with the existing Reg. 308 and the proposed revisions to Reg. 308 will be assumed in this study. In practice, this level of compliance would only be approached with a greatly enhanced monitoring and enforcement effort by the MOE.

Incinerators of Non-Hazardous Wastes

The MOE has established policies for air pollution control on refuse incinerators and the combustion of refuse in incinerators. The policies require that 'state-of-the-art' air pollution control systems be installed on all new incinerators. Furthermore, the MOE is participating in the formulation of federal guidelines for municipal incineration. (Emission numbers have been developed but are not available.)

These new policy developments are independent of the proposed revisions to Reg. 308 and, to a large extent, anticipate the kinds of changes that the proposed revisions are intended to bring about. Therefore, it will be assumed that the changes to Reg. 308 will have no significant effect on the abatement technologies required for new incinerators of non-hazardous wastes.

Other Regulations

For the purposes of the economic assessment, and to be consistent with the thinking underlying the proposed revisions to Reg. 308, it will be assumed that the proposed revisions to Reg. 308 will not supercede the regulations on P. 55 of the CAP document (MOE, 1987) except where explicitly stated as doing so in the document (e.g. Reg. 296).

Other Jurisdictions

It will be assumed that Ontario is the only jurisdiction contemplating changes in the regulation of air pollution. Possible changes in other jurisdictions will not be considered.

Changes in Technology

Only those technologies that currently meet the criteria for Level 1 (LAER), Level 2 (BACT-EA) and Level 3 (NSPS) will be considered in the economic assessment.

Units of Measurement

Metric measures will be used for all units of mass, volume and distance unless otherwise stated. All monetary values will be expressed in 1986 Canadian dollars.

References - Chapter 2

Lewis, R.G., 1986. *Problems Associated with Sampling for Semi Volatile Organic Chemicals in Air*. Proceedings of the 1986 U.S. EPA/APCA Symposium on Measurements of Toxic Air Pollutants, Raleigh, North Carolina, April.

Ministry of the Environment (MOE), 1987. *Discussion Paper Air Pollution - General Regulation (Regulation 308)*. November. CAP (Clean Air Program) Discussion Paper.

TABLE 2.1

CONTAMINANTS CONSIDERED

VOLATILE ORGANIC COMPOUNDS

Chlorinated

- carbon tetrachloride
- chloroform
- ethylene dichloride
- phosgene
- vinyl chloride
- trichloroethylene
- 1,1,1-trichloroethane (methyl chloroform)
- epichlorohydrin
- methylene chloride
- perchloroethylene
- hexachlorocyclopentadiene
- 4,4-methylene-bis-2-chlorol-aniline

Aliphatics

acrylonitrile	(nitrile)
ethylene	
ethylene dibromide	(alkyl halide)
mercury (alkyl)	(alkyl)
nickel carbonyl	(organo metal)

Aromatic

- benzene
- coal tar pitch volatiles (soluble fraction)
- ethylbenzene
- styrene
- toluene
- xylenes

Esters

- butyl acrylate
- ethylene glycol butyl ether acetate (butyl Cellosolve acetate)
- ethylene glycol ethyl ether acetate (Cellosolve acetate)
- propylene glycol monomethyl ether acetate

TABLE 2.1 (Continued)

Alcohols

Ethers

- ethylene oxide
- propylene oxide
- ethylene glycol butyl ether (butyl Cellosolve)
- ethylene glycol ethyl ether (Cellosolve)
- propylene glycol methyl ether

Aldehydes

- formaldehyde
- propionaldehyde

Ketones

- 2-butanone (methyl ethyl ketone)
- methyl isobutyl ketone

Mercaptans

- mercaptans

Other

- acrylonitrile
- mercury alkyl
- nickel carbonyl

PARTICULATES associated:

Organic

- benzo(a)pyrene
- thiourea

Metals

- beryllium
- cadmium
- chromium
- chromium (di, tri, and hexavalent forms)
- lead
- manganese compounds
- nickel
- calcium cyanide (as total salt)
- potassium cyanide (as total salt)
- sodium cyanide (as total salt)
- tin

TABLE 2.1 (Continued)

OTHER PARTICULATES

- arsenic
- asbestos (fibres of length greater than 5 micrometers)
- asbestos (total)
- inhalable particulates (less than 10 micrograms)
- selenium
- silica-respirable (less than 10 micrometers in diameter)
- suspended particulate matter (particulate less than 44 microns in size)
- fluorides (total)

SEMI-VOLATILE ORGANICS

chlorinated dibenzo dioxins (CDDs)	(chlorinated)
mixture of chlorinated dibenzo dioxins and chlorinated dibenzo furans	(chlorinated)
phenol	(aromatic)
polychlorinated biphenyls	(chlorinated)
trichlorophenols	(chlorinated)
naphthalene	(aromatic)
pentachlorophenol	(chlorinated)
tetrachlorophenols	(chlorinated)
polycyclic aromatic hydrocarboons (PAHs)	(aromatic)
trichlorobenzenes	(chlorinated)
1,2,4-trichlorobenzene	(chlorinated)
pentachlorobenzenes	(chlorinated)
tetrachlorobenzenes	(chlorinated)
toluene diisocyanate	(aromatic)
methane diphenyl diisocyanate	(aromatic)

PESTICIDES

- captan
- chlordane

CORROSIVES

Acids

- hydrogen chloride
- hydrogen cyanide
- sulfuric acid
- propionic acid

TABLE 2.1 (Continued)

Bases

- ammonia
- potassium hydroxide
- sodium hydroxide

OTHER

- arsine
- chlorine
- chlorine dioxide
- mercury
- nitrogen oxides
- nitrous oxide
- ozone
- phosphine
- sulfur dioxide
- hydrogen sulfide
- total reduced sulfur (TRS) as equivalent H_2S (from Kraft Pulp Mills)

TABLE 2.2

LEVEL OF CONTROL BY SCENARIO

Contaminant Group	Scenarios A Initial	 B More Stringent	 C Less Stringent	 D 2-Tier
Volatile Organic Compounds (Odorous and Non-Odorous)				
Chlorinated	1	1	2	1
Aliphatics	3	2	3	2
Aromatics	2	1	3	2
Esters/Alcohols/Ethers/ Aldehydes/Ketones	2	1	3	2
Mercaptans	3	2	3	2
Particulates associated:				
Organics	1	1	2	1
Metals	1	1	2	1
Other Particulates	2	1	3	2
Semi-Volatile Organics	2	1	3	2
Pesticides	2	1	3	2
Corrosives				
Acids	2	1	3	2
Bases	2	1	3	2
Other	2	1	3	2
Other	2	1	3	2

Phasing In:

Phasing in for each of the above scenarios will be as in case 1 below. A fifth scenario (E) will also be considered which is identical to scenario A, but is phased in more slowly (case 2).

Phasing In	A,B,C,D Case 1	E Case 2
New Facilities	1989	1989
Existing Facilities		
Contaminant Group:		
Level 1 (high hazard)	1994	2004
Level 2 (medium hazard)	1994	2009
Level 3 (low hazard)	1994	2014

Note: Levels 1, 2 and 3 have been assigned for the purposes of this study only and may not reflect the actual levels of control imposed in any revisions to Reg. 308.

3.0 AIR POLLUTION CONTROL EQUIPMENT FOR PARTICULATE MATTER

3.1 Inertial Separators

Inertial separators are primarily used for collecting medium- and coarse-sized particulate matter. The construction of inertial separators is usually relatively simple, and initial costs and maintenance costs are generally lower than for most other types of dust collectors. Collection efficiencies, however, are usually not high. Although suitable for medium-sized particulates (15 to 40 microns), ordinary inertial separators are generally unsuitable for fine dusts or metallurgical fumes. Dusts with a particle size ranging from five to ten microns are normally too fine to be collected efficiently. In some cases, however, small diameter, high-efficiency cyclones can be effective in collecting particles in the five-micron range.

Single-Cyclone Separators

A cyclone, which is an inertial separator without moving parts, separates particulate matter from a carrier gas by transforming the velocity of an inlet stream into a double vortex confined within the cyclone. In the double vortex, the entering gas spirals downward at the outside and spirals upward at the inside of the cyclone outlet. The particulate matter, because of their inertia, tend to move toward the outside wall, from which they are led to a receiver.

Cyclones can be designed to handle a wider range of chemical and physical conditions of operation than most other types of collection equipment. Because of its versatility and low cost, the single-cyclone separator is the most widely used of the dry centrifugal separators.

For high efficiency, the separating forces should be large and the dust removal effective so that separated dust is not re-entrained. In general, cyclone efficiency increases with an increase in the following: (1) density of the particulate matter, (2) inlet velocity into the cyclone, (3) cyclone body length, (4) number of gas revolutions, (5) ratio of cyclone body diameter to cyclone outlet diameter, (6) particle diameter, (7) amount of dust entrained in carrier gas, and (8) smoothness of inner cyclone wall.

An increase in the following will decrease the overall efficiency; (1) carrier gas viscosity, (2) cyclone diameter, (3) gas outlet diameter, (4) gas inlet duct width, (5) inlet area, and (6) gas density.

Other Types of Cyclone Separators

High-efficiency cyclones are made more effective than simple cyclones by increasing the body length and decreasing the diameter. This leads to longer retention time and greater centrifugal force on the particulate, which results in greater separation. However, the pressure drop increases, resulting in greater power costs.

A multiple-cyclone separator consists of a number of small-diameter cyclones operating in parallel, having a common gas inlet and outlet. It would likely be used when there is a high throughput of gas and high collection efficiency is desired. The flow pattern differs from a conventional cyclone in that the gas, instead of entering at the side to initiate the swirling action, enters at the top and has this swirling action imparted to it by a stationary vane positioned in its path.

Several types of collectors are readily available in which centrifugal force is supplied by a rotating vane. The collector serves both as an exhaust fan and dust collector (mechanical and centrifugal separators). In operation, the rotating fan blade exerts a large centrifugal force on the particulates, ejecting them from the tip of the blades to a skimmer bypass leading into a dust hopper. Power and maintenance costs for these types of collectors are higher than for other types of inertial separators, while collection efficiencies are higher than those of simple cyclones.

Cyclones typically have a 90% collection efficiency on three to ten micron particle sizes and 98% on larger sizes. Cyclones are ineffective on fine particles. Equipment and operating costs are described in Appendix A.

3.2 Wet Collection Devices

Wet collection devices use a variety of methods to wet the contaminant particles in order to remove them from the gas stream. There are also wide ranges in the cost, collection efficiency and the power requirements. The collection efficiency varies widely with different designs. Most collectors decline rapidly in efficiency for particles between one and ten microns.

Wet collectors have the following advantages: a constant pressure drop (at constant volume), no secondary dust problem in disposing of the collected dust, and the ability to handle high-temperature or moisture-laden gases. Corrosive gases or aerosols can also be handled, but corrosion-resistant construction may add materially to the cost. Space requirements are reasonably small. Disposal of the waste water or its clarification for reuse may, however, be difficult or expensive.

Theory of Collection

The principal mechanisms by which liquids may be used to remove aerosols from gas streams are as follows:

- wetting of the particles by contact with a liquid droplet.
- impingement of wetted or unwetted particles on collecting surfaces followed by their removal from the surfaces by a flush with a liquid.

Mechanisms for Wetting the Particle:

- Impingement by spray droplets
- Diffusion - When liquid droplets are dispersed among dust particles, the dust particles are deposited on the droplets by Brownian motion. This is the principal mechanism in the collection of submicron particles.
- Condensation - If a gas is cooled below the dewpoint in passing through a wet collector, then condensation of moisture occurs, the dust particles acting as condensation nuclei. This effective increase in the particle size makes subsequent collection easier.

Types of Wet Collection Devices:

- Spray Chambers
- Cyclone-Type Scrubbers
- Orifice-Type Scrubbers

- Mechanical Scrubbers
- Mechanical, Centrifugal Collector with Water Spray
- High-Pressure Sprays
- Venturi Scrubbers
- Packed Towers
- Wet Filters

Drawbacks to some of the different wet collection devices include: possible corrosion and erosion problems, the wet collection of dust, and the fact that a downstream mist eliminator is usually required. Equipment and operating costs are described in Appendix A.

Typical collection efficiencies are 99% on particles 2 um and larger and 10% on particles 0.1 um and smaller.

3.3 Baghouses (Fabric Filter)

When high collection efficiency of small particles is required, the most widely used method consists of separating the dust from the air by means of a fabric filter. The fabric is usually made into bags of tubular or envelope shape. The entire structure housing the bags is called a baghouse.

Filter fabrics normally used to remove dust and fumes from airstreams are usually woven with relatively large open spaces, sometimes 100 microns or larger in size. Small particles are initially captured and retained on the fibers of the cloth by means of interception, impingement, diffusion, gravity, settling, and electrostatic attraction. Once a mat or cake of dust is accumulated, further collection is accomplished by sieving, as well as by the previously mentioned mechanisms. The cloth then serves mainly as a supporting structure for the dust mat responsible for the high collection efficiency. Periodically, the accumulated dust is removed for disposal. Some residual dust remains and serves as an aid to further filtering.

The resistance to gas flow offered by clean filter cloth is determined by the fibres of the cloth and the manner in which they are woven together. The increase in resistance of the dust mat and filter fabric can be correlated with (is dependent upon): filtration velocity, gas viscosity and density, particulate concentration, elapsed time, and dust characteristics such as particle size, true specific gravity, particle shape factor, and a factor for the percent of voids or the degree of packing.

The types of filtering media commonly used in baghouses are: cotton, wool, nylon, cynol (an acrylic fibre), orlon and dacron, teflon, glass and filament and staple yarns.

As dust accumulates on the filtering elements, the pressure loss increases until some maximum desirable value is reached. The filter then must be cleaned to reduce the pressure loss. The baghouse may be cleaned using manual cleaning, mechanical shakers, pneumatic shakers, bag collapse, sonic cleaning, reverse airflow and reverse-air jets. The cleaning cycles may be manually initiated, semi-automatic, fully automatic, or continuous cleaning.

The limitations of fabric filtration are: gas temperatures cannot exceed 290° C (554° F), as damage to the fabric will result; the fabric may be susceptible to chemical attack; and the filter may be fouled by acid mist, condensation, or tacky particles. The problems associated with high temperature and chemical attack can be partially mitigated through the use of special fabrics.

Removal efficiencies on particles 2 um and larger are typically 99.9%. Equipment and operating costs are described in Appendix A.

3.4 Electrostatic Precipitators

Electrostatic precipitators operate on the principle that when particles in a gas are exposed to gas ions in an electrostatic field, they will become charged and migrate under the action of the field. Electrical precipitation first involves gas ionization followed by particle collection, which is accomplished by the following means:

a) Production of an electrostatic field to cause charging and migration of dust particles
b) Gas retention to permit particle migration to a collection surface
c) Prevention of re-entrainment of collected particles
d) Removal of collected particles from the equipment

There are two general classes of electrical precipitators:

- single-stage, in which ionization and collection are combined;

- two-stage, in which ionization is achieved in the first portion of the equipment, followed by collection in another.

The use of electrical precipitators for the collection of air contaminants has grown because of many inherent advantages, some of which are listed below:

- High efficiency can be attained. Efficiency may exceed 99 percent in some cases.

- Very small particles can be collected. There is no theoretical lower limit to the size of a particle that can be collected.

- Dusts may be collected dry for easier recovery of valuable material.

- Pressure and temperature drops are small. The pressure drop through an electrical precipitator seldom exceeds 0.5 in water.

- Precipitators are normally designed to operate continuously with little maintenance over long periods of time.

- There are very few, if any, moving parts, which tends to reduce the maintenance required.

- Precipitators can be used at high temperatures. Temperatures up to about 370° C (700° F) are normal. Special designs have been used for temperatures as high as 700° C (1,300 ° F), but ordinarily the temperature does not exceed 540° C (1,000° F).

- Precipitators can be used to collect acid and tar mists, which are difficult, if not impossible, to collect by other methods.

- Extremely corrosive materials can be collected with special construction.

- Collection efficiency may be adjusted to suit the application by increasing the unit size.

- Very large gas flow rates can be handled.

- The power requirements for the flow handled are low.

The following are the primary disadvantages associated with electrostatic precipitators:

- Initial cost is high. In most cases, the investment is greater than that required for any other form of air pollution control.

- Precipitators are not easily adapted to variable conditions. Automatic voltage control helps to a great extent, but precipitators are most efficient when operating conditions remain constant.

- Some materials are extremely difficult to collect in an electrical precipitator because of very high or low resistivity or other causes. In some cases, these factors alone make the use of electrical precipitation un-economical, if not physically impossible.

- Space requirements may sometimes be greater than those for a baghouse. In general, this is true when high collection efficiency is required for materials difficult to collect by precipitation.

- Electrical precipitation is not applicable to the removal of gases.

- The use of a precleaner, generally of the cyclonic type, may be required to reduce the dust load on a precipitator.

- Special precautions are required to safeguard personnel from the high voltage.

Two-Stage Electrostatic Precipitators

The two-stage unit differs from the one-stage unit in that the contaminated gas is first passed through a variable-strength ionizing field, before being subjected to a separate uniform field where the charged particles are collected.

Among the types of operations that have been successfully controlled by standard two-stage precipitators are: high-speed grinding machines, meat product smokehouses, continuous deep fat cookers, asphalt saturators, galvanizing kettles, rubber-curing ovens, carpeting dryers, and vacuum pumps.

For the precipitator mentioned above, removal efficiencies can be expected to be 95-99% for collection of sub-micrometer particulate matter. Equipment and operating costs are described in Appendix A.

3.5 Other Particulate-Collection Devices

There are other devices of more simple designs that have very limited application in the control of air particulate matter. These include settling chambers, impingement separators, and panel filters. Most are used principally as precleaners, but some, such as paper filters for paint spray booths, are used as final collectors where the air contaminant is of large size or where the grain loading is very small.

Settling Chambers

Settling chambers are one of the simplest and earliest types of collection devices. The most common form consists of a long, boxlike structure in the exhaust system. The velocity of the dirty gas stream is reduced by the enlargement in cross-sectional area, and particles with a sufficiently high settling velocity are collected by the action of gravity forces. A very long chamber is required to collect small particles. Structural limitations usually restrict the usage of simple settling chambers to the collection of particles 40 microns or greater. Their greatest use is as a precleaner to remove coarse and abrasive particles for the protection of the more efficient collection equipment that follows the chamber.

Impingement Separators

When a gas stream carrying particulate matter impinges on a body, the gas is deflected around the body, while the particles, because of their greater inertia, tend to strike the body and be collected on its surface. A number of devices use this principle. The bodies may be in the form of plates, cylinders, ribbons, or spheres.

Impingement separators are best used in the collection of mists. The collected droplets form a film on the surface and then gradually drip off into a collection pan or tank. Conversely, collected dry dust tends to become re-entrained when it falls off the collecting surface. For this reason, water sprays are sometimes used to wash off the collected dust.

Panel Filters

Panel filters are most commonly used in air conditioning installations, though they do have several important industrial applications. Filters are supplied in units of convenient size, usually about 20 by 20 inches, to facilitate installation and cleaning. Each unit consists of a frame and a pad of filter material. The frames of similar units may be joined together to form a panel. These filters are classified into two types, viscous and dry.

Filters are called viscous because the filter medium is coated with a viscous material to help catch the dust and prevent re-entrainment. The filter pad consists of materials such as glass fibers, hemp fibers, animal hair, corrugated fiberboard, split wire, or metal screening. When the maximum allowable dust load has accumulated, the metal trays are removed, washed or steamed, reoiled, and put back into service. Other pads are thrown away when they become loaded with dust as shown by their increased resistance to airflow. A common industrial application of the wire screen-type filter is found in collection of mist generated from cutting oils used by metal-cutting machines.

Dry filters are supplied in units similar to viscous filters, except that the depth is usually greater. The filter materials usually have smaller air passages than the viscous filters do, and hence, lower air velocities must be used to prevent excessive pressure drop. Dry filters are usually operated at 30 to 60 feet per minute (fpm), as contrasted with 300 to 500 fpm for viscous filters. In order to increase the filtering area per unit of frontal area, the filter pads are often arranged in an accordion form with pleats and pockets. When the pressure drop becomes excessive because of accumulated dust, the dry type pads are discarded. Dry filters are frequently used to collect the overspray from paint-spraying operations.

Precleaners

Devices of limited efficiency are often used ahead of the final cleaner. If the gases contain an appreciable amount of hard, coarse particles, a precleaner can materially reduce erosive wear on the more efficient (and more expensive) final collector. If the collected material has value, a precleaner ahead of a scrubber can sometimes collect the bulk of it in a more usable form. Devices generally used as precleaners are settling chambers and centrifugal separators.

References - Chapter 3

Calvert, S. and Englund, H.M., 1984. *Handbook of Air Pollution Control Technology.* John Wiley and Sons Inc., Toronto.

Chemical Engineering, 1983. *Copper smelters face tougher arsenic emission standards,* Currents, August 8, pg. 27.

Dunbar, D. and Rust, G., 1985. *BACT/LAER (Best Available Control Technology/Lowest Achievable Emission Rate).* Clearinghouse: A Compilation of Control Technology Determinations: Volume II- C, Appendix G - Source Type Codes 8-12. EPA Report No. EPA-450/3-85-016D.

Jaasund, S.A., 1987. *Electrostatic Precipitators: Better Wet than Dry.* Chemical Engineering, Engineering Feature, November 23, Pg. 159-163.

Orem, S.R., 1982. *Air Pollution Control Technology: An Overview.* Journal of the Air Pollution Control Association, March, Volume 32 (3), Pg. 246-249.

U.S. Department of Health, Education and Welfare, 1967. *Air Pollution Engineering Manual.* Public Health Service Publication No. 999-AP-40, Cincinnati.

U.S. EPA, 1980. *The Cost of Clean Air and Water: U.S. EPA Report to the Congress*, Journal of the Air Pollution Control Association, January, Volume 30 (1), Pg. 60-63.

4.0 GAS AND VAPOUR CONTROL EQUIPMENT

4.1 Absorption

Gas absorption (scrubbing) is the mechanism whereby one or more constituents are removed from a gas stream by dissolving them in a selective liquid solvent.

Gas absorption equipment is designed to provide thorough contact between the gas and liquid solvent in order to permit interphase diffusion of the materials. The rate of mass transfer between the two phases is largely dependent upon the surface exposed. Other factors governing the absorption rate, such as solubility of the gas in the particular solvent and degree of chemical reaction, are characteristic of the constituents involved and are more or less independent of the equipment used. This contact between gas and liquid can be accomplished by dispersing gas in liquid or vice versa.

Absorbers that disperse liquid include packed towers, spray towers or spray chambers, and venturi absorbers. Equipment that uses gas dispersion includes tray towers and vessels with spraying equipment.

A packed tower is a tower that is filled with one of the many available packing materials (such as raschig rings, berl saddles, and intalox saddles). The packing is designed to expose a large surface area to the flow passing through a tower. When this packing surface is wetted by the solvent, it presents a large area of liquid film for contacting the solute gas. The flow through a packed column is almost always counter current since this results in the highest possible contact efficiency. Liquid is introduced at the top to trickle down through the packing while gas is introduced at the bottom to pass upward through the packing.

In contrast to packed towers, where gas and solvent are in continuous contact throughout, the packed bed, plate or tray towers employ stepwise contact by means of a number of trays or plates that are arranged so that the gas is dispersed through a layer of liquid on each plate. Each plate is more or less a separate stage, and the number of plates required is dependent upon the difficulty of the mass transfer operation and the degree of separation desired.

Interphase contact in spray-type absorbers (spray towers and spray chambers) is achieved by dispensing the liquid in the form of a spray and passing the gas through this spray. In order to present a large liquid surface available for contact, sprays of droplets ranging in size from 500 to 1,000 microns are necessary. Fine droplets, however, require high pressure drops across the spray nozzles, and there is danger of liquid entrainment at all except very low gas velocities.

Spray chambers or towers have been used extensively for control of particulate matter, but their use for pure gas absorption seems to be limited to air conditioning or deaeration of water. These chambers may also be used for some highly soluble gases when the degree of required removal is small, but in air pollution control work, this type of operation is not common. They have been used as precleaners for particulate removal from gas streams where other devices are used for ultimate control of air pollution.

Like spray towers and spray chambers, equipment using the venturi principle is primarily used for removing particulates from gas streams, though it has application to gas absorption. In gas absorbers, the necessary interphase contact is obtained by differences between the velocity of gas and liquid particles, and by turbulence created in the venturi throat. Dispersion in venturi devices is achieved in two ways: by injecting the liquid into the gas stream as it passes through the venturi, or by admitting the gas to the liquid stream as it passes through the venturi. In the latter case, the venturi is also a vacuum-producing device and inspirates the gas in to the venturi throat. With both types, a gas-liquid separation chamber is necessary to prevent entrainment. This can be a simple tank, with the stream from the venturi tube impinging on the liquid surface, or, more efficiently, a cyclone-type separator.

Venturi absorbers obtain a high degree of liquid-gas mixing but have the disadvantage of a relatively short contact time. Another major disadvantage is the high pressure drop across them, leading to high power consumption.

Equipment and operating costs are described in Appendix A.

Removal efficiencies of about 99% or better for acid gases and 95% or better for odorous gases can be expected.

4.2 Adsorption

Adsorption is the name for the phenomenon by which molecules of a fluid contact and adhere to the surface of a solid. By this process, gases, liquids, or solids, even at very small concentrations, can be selectively captured or removed from the airstreams with specific materials known as adsorbents.

A change in the composition of the fluid contacting the adsorbent when one or more of the components are adsorbed by the adsorbent. While adsorption can occur at all solid interfaces, it is usually small unless the solid is highly porous and possesses fine capillaries. The most important characteristics of solid adsorbents are their large surface-to-volume ratios and preferential affinity for individual components.

In most processes involving adsorption, the operation involves three steps. First, the adsorbent is contacted with the fluid, and a separation by adsorption results. Second, the unadsorbed portion of the fluid is separated from the adsorbent. In the case of gases, this operation is completed on the passage through the adsorbent bed. Third, the adsorbate is removed from the adsorbent, which thereby regenerates the adsorbent. In some cases, the adsorbent is regenerated without recovery of the adsorbate. In the treatment of domestic water with finely divided activated carbon, both the adsorbent and the adsorbate are separated from the fluid and discarded.

Regeneration, which involves raising the temperature of the adsorbent, may be performed by several methods, depending on the adsorbate. In the recovery of chlorine and sulfur dioxide from silica gel, the adsorbent is heated indirectly with brine. In the recovery of solvents, low-pressure steam is used and the condensed vapours are separated from the water by decantation or distillation, or both.

Use of Activated Carbon in Air Pollution Control

Activated carbon is the adsorbent most suitable for removing organic vapours. Carbon adsorbs substantially all the organic vapour from the air at ambient temperature, regardless of variation in concentration and humidity conditions.

Two types of activated carbon adsorbers are commonly used, the Fixed-Bed Adsorber and the Continuous Adsorber.

Operational Problems

- Particulate Matter

An activated-carbon adsorption bed should be protected from particulate matter that can coat the surface of the carbon. Without this protection, the effective area and the ability to adsorb will be impaired, and the life of the carbon will be reduced if the material is not removed by regeneration. Carbon adsorbers can be adequately protected from particulate matter with efficient filters and without excessive increase in the total pressure drop.

- Corrosion

Corrosion of adsorbers occurs when steam is used in stripping solvents from activated carbon. The amount of this corrosion is intensified with increasing steam temperature.

Corrosion can be controlled or reduced by the use of stainless steel or by application of protective coating of a baked phenolic resin.

- Polar and Nonpolar Compounds

Polar and nonpolar solvents are equally adsorbed by activated carbon, but recovery of polar compounds on stripping with steam requires an additional step of fractionation by distillation to effect a separation from aqueous solution.

Performance Characteristics

85-99% removal of contaminants
Not effective on true gases
85-99% recovery of contaminants in regenerable system
Condensables and particulates foul carbon, often irreversibly
Fire protection may be required

Cost Parameters

Equipment and operating costs are described in Appendix A.

The operating cost is extremely variable. Pressure drop, horsepower and carbon consumption or regeneration change are the main items of cost for single bed systems. Steam, cooling water, power, and wastewater disposal are the main items of cost for a regenerable system.

4.3 Chemical Reaction

Nitrogen Oxides (NO_x)

In combustion, two mechanisms are at work creating NO_x.

"Thermal" NO_x is created when atmospheric oxygen and nitrogen combine at very high flame temperatures. In utility boilers, most of this type of NO_x is in the form of nitric oxide (NO) (up to 95 percent). In the stack plume, this NO combines with oxygen from the atmosphere to form a yellow-brown toxic gas, NO_2. "Fuel" NO_x is produced by a second mechanism, the reaction of fixed fuel nitrogen and oxygen in the combustion air. This form of NO_x, like thermal NO_x, is made up mostly of NO (up to 95 percent). In both cases, NO_2 is created as the NO leaves the stack and oxidizes in the atmosphere.

The two mechanisms by which NO_x is produced require somewhat different methods of control. Thermal NO_x production rates are affected by the flame temperature, the amount of excess oxygen available and the residence time in the peak flame temperature regions. Fuel NO_x production is much more dependent upon the amount of fixed nitrogen in the fuel, the amount of oxygen available for oxidation of the fixed fuel nitrogen and on the presence of local oxygen-rich pockets within the fuel/air mixture. Unlike thermal NO_x, it is not very dependent upon the flame temperature.

NO_x Emission Control by Combustion Modification

In general, combustion modifications are designed to reduce NO_x emissions by one or more of the following mechanisms: limiting the residence time in the primary flame zone, reducing the flame temperature, and reducing the rapid mixing of fuel and secondary air. However, each unit design seems to react differently, so that caution must be exercised when trying to apply the results of one unit to another. NO_x emission reduction programs must be tailored for each type of unit. Several combustion modification methods are described below.

Staged Combustion Air (SCA)

One of the most effective NO_x-reducing methods applied to steam generators has been the splitting of combustion air. With two-stage combustion, only 90 to 95 percent of the theoretical combustion air requirement is injected at the burner. The remaining air is introduced a few feet downstream of the burner to complete combustion over a somewhat longer zone. With this arrangement, the total excess air rate is held to the same figure used during normal firing, that is, about ten percent. This delayed air introduction was found to reduce NO_x concentrations in flue gases by 40 to 50 percent.

Lowering Excess Air (LEA)

NO_x concentrations can be lowered by reducing excess air rates. The minimum possible oxygen concentration is about 0.2 percent (approximately one percent excess air). Nevertheless, simple lowering of excess air does not appear to be as effective nor as explosion proof as two-stage combustion.

Low NO_x Burners

Low NO_x Burners have reduced both thermal and fuel NO_x emissions in retrofitted power generation applications by up to 40 percent. The removal efficiency is a function of the fuel used and furnace design. Newer burner designs may be able to reduce NO_x still further.

Several of the combustion modifications are used or are suggested for industrial boilers. They include lower excess air (LEA), flue gas recirculation (FGR) and staged combustion air (SCA). These modifications can be used by themselves, as a combination of combustion modifications; in conjunction with Selective Noncatalytic Reduction (SNCR); or with Selective Catalytic Reduction (SCR). The removal efficiencies increase with use of SNCR (35-45% removal) and SCR (65-75% removal).

Sulphur Dioxide & Hydrogen Chloride

Sulphur Dioxide (SO_2) and Hydrogen Chloride (HCl) removal is accomplished by chemical reaction in flue gas desulphurizing systems of two types, wet and dry. In the wet system, SO_2 is absorbed by an alkaline solution or slurry and reacts to produce sulphur salts. Dry systems spray alkaline dust or slurry into the flue gas, and the resulting reacted material is dry and can be readily removed by particulate matter controls.

Limestone slurry is the most common type of flue gas desulphurization process used on large SO_2 emitters. It can remove up to 96 percent SO_2, but operating efficiencies are close to 90 percent. The waste produced, a calcium sulphite or sulphate, is disposed in landfill.

Another wet process, the lime dual alkali process, uses two reagents and regeneration. It achieves removal efficiencies of up to 95 percent. Waste is disposed in landfill. In the dry system, absorption of SO_2 and other acid gases has been accomplished in industrial processes, municipal and non-municipal incinerators and power boilers using high sulphur fuels.

Spray dryers spray lime or lime slurry through atomizers into the flue gas. The water content of the slurry evaporates and the mixed salts and fly ash are removed in a particulate collector downstream. If a baghouse is used to collect the particulate some additional chemical reaction between collected dusts and unreacted acid gases may take place, further enhancing acid gas removal.

4.4 Incineration

Afterburners are used to incinerate combustible aerosols, particulates, gases, or vapour emissions. Emissions of organic materials can be readily reduced or eliminated and the concentrations of particulate matter can be reduced if all or part of the solids are combustible. Thus visible emissions can sometimes also be reduced. Incineration is particularly useful for the destruction of emissions consisting of materials with low odour thresholds. In some applications, it is possible to recover heat from the incinerated gases and thereby reduce the cost of operation.

There are two types of afterburners, direct fired and catalytic. The direct-fired type is much more commonly employed because of greater adaptability and higher efficiency. Catalytic afterburners have been used to control some processes that emit organic vapours. The use of a catalyst promotes some combustion reactions at lower temperatures than those normally required by direct-fired afterburners. The operating and thus the fuel costs of catalytic afterburners may be lower than those of the direct-fired type. However, at lower temperatures, incomplete combustion may occur in any afterburner. If odour concentrations are not reduced sufficiently or partially oxidized to other malodorous products, odours may be increased. To overcome this, incineration at higher temperatures with adequate oxygen is required.

Direct-fired afterburners have proved capable of controlling combustible emissions to very low concentrations from a wide variety of sources. They are the most commonly used air pollution control devices where emissions of combustible aerosols, vapours, gases, and odours occur. Removal efficiencies of 99% and higher are achieved.

Catalytic afterburners have found their greatest use in the control of solvent and organic vapour emissions. These emissions are created in operations such as metal-coating ovens, foundry core ovens, fabric-backing and fabric-coating ovens, and other industrial operations using ovens. Removal efficiencies of up to 95% can be achieved at relatively high temperatures.

4.5 Condensation

Condensable air contaminants can be discharged into the atmosphere in the form of gases or vapours. In specific instances, control of vapour-type discharges can best be accomplished by condensation, rather than other means such as absorption, adsorption, or incineration. Other applications require a condenser to be an integral part of other air pollution control equipment. In these cases, a condenser reduces the load on a more expensive control device or removes vapour components that may affect the operation.

Two types of condensers are commonly used, surface and contact condensers. Vapours can be condensed either by increasing pressure or extracting heat. Air pollution control condensers operate usually in a cooling mode through removal of heat from the vapour. Condensers differ principally in the means of cooling. In surface condensers, the coolant does not contact the vapours or condensate. In contact condensers, coolant, vapours, and condensate are intimately mixed.

References - Chapter 4

Chemical Engineering, 1980. *Solvent-recovery system saves costs and cleans air.* New Products & Services, March 10, pg. 91-92.

Chemical Engineering, 1982. *Estimating costs of air-pollution control systems Part XIII: Costs of gas absorbers.* Cost File, October 4, Pg. 135-136.

Chemical Engineering, 1983. *A fluegas wet scrubber with a specially hydrated reagent....* Chementator, December 12, Pg. 17-18.

Chemical Engineering, 1983. *Firms dust off old technology to meet stricter NO_x limits.* Currents, February 7, pg. 29-30.

Chemical Engineering, 1984. *Controlling NO_x emissions can....* Chementator, April 30, Pg. 18-19.

Chemical Engineering, 1986. *Fertilizer from NO_x and SO_x in flue gas....* Chementator, January 6, Pg. 10-11.

Dunbar, D. and Rust, G., 1985. *BACT/LAER (Best Available Control Technology/Lowest Achievable Emission Rate).* Clearinghouse: A Compilation of Control Technology Determinations: Volume II- C, Appendix G - Source Type Codes 8-12. EPA Report No. EPA-450/3-85-016D.

Karlsson, H.T. and Rosenberg, H.S., 1980a. *Technical Aspects of Lime/Limestone Scrubbers for Coal-Fired Power Plants Part I: Process Chemistry and Scrubber Systems*, Volume 30 (6), pp. 710-716, June.

Karlsson, H.T. and Rosenberg, H.S., 1980b. *Technical Aspects of Lime/Limestone Scrubbers for Coal-Fired Power Plants Part II: Instrumentation and Technology.* Journal of the Air Pollution Control Association, Control Technology News, Volume 30 (7), pp. 822-828, July.

Ontario Hydro, 1988. *Fluid Gas Desulphurization Program Environmental Assessment.* February.

Vatavuk, W.M. and Neveril, R.B., 1983. *Estimating costs of air-pollution control systems Part XIV: Costs of carbon adsorbers.* Chemical Engineering, Cost File, January 24, 1983, pg. 131- 132.

Vatavuk, W.M., and Neveril, R.B., 1984. *Estimating costs of air-pollution control systems Part XVIII: Gaseous emissions control.* Chemical Engineering, Cost File, April 30, Pg. 95-98.

5.0 INDUSTRY SECTORS

5.1 Sectors

The sectors to be evaluated in this study were selected by the MOE and are listed below.

- open pit mining
- food industry
- pulp and paper and allied products
- iron and steel industry
- foundries
- non-ferrous smelters and refineries
- automotive industry
- inorganic chemical manufacturing
- petroleum refineries
- asphalt paving
- petrochemical products manufacturing
- electrical power generation
- waste disposal facilities
- municipal incinerators

5.2 SIC Categories, Processes and Methodology

The fourteen sectors listed above were segregated first into four digit Standard Industrial Classification (SIC) categories and these were further separated into individual processes. Based on discussions with the MOE, 60 SIC categories covering 153 processes were initially considered. For some of the SIC categories, information was not available because those processes did not exist in Ontario; consequently, information was obtained on 54 SIC categories covering 148 processes. Further combining of SIC categories occurred primarily because of the similarity of some processes, with the result that the report provides details on 43 four-digit SIC categories covering 136 processes. Table 5.1 lists the sectors, SIC categories and number of processes for which information was obtained.

Methodology

During this study, quantitative data were collected on the following items:

- Ontario industrial, commercial and municipal processes falling within the SIC categories identified above.
- Production and capacity by process.
- Employment by process.
- Process emissions and emission factors.
- Existing emission controls and controls required to reduce air emissions to levels indicated in the proposed revisions to Reg. 308.
- Capital and operating costs of control for existing equipment and for equipment likely to be necessary to achieve levels of air emissions of indicated in the proposed revisions.

Information on the foregoing items was obtained from available literature and literature searches; industrial associations; interviews, telephone inquiries, and correspondence with private and public sector representatives; in-house consultants; government reports and files. Sector Profiles for 1986 published by the federal government were used extensively to characterize industries.

Once data was gathered from one or more of these sources, it was used to characterize a particular industry or group of industries. In a few cases, complete data was available. More often, the data was incomplete and missing data was filled in by scaling up from a known plant's capacity or number of employees. In a few cases, assumptions about the processes and the capacity of an industry had to be made because of a lack of data.

Process emission factors were obtained directly or calculated from information in the literature. The amount of annual contaminants emitted was then calculated. In some cases, the actual annual contaminants emitted was known by process or by a specific plant and emission factors were generated based upon these actual emissions.

Control equipment for the existing and alternative abatement levels was determined primarily from information contained in the BACT/LAER Clearing house: A Compilation of Control Technology Determinations (Dunbar and Rust, 1985).

5.3 Industry Characteristics and Emissions

The industry characteristics (using 1986 data) and contaminant emissions by process are described for each sector in the following section.

5.3.1 Open Pit Mining Industry

As shown in Table 5.2A, there are four open pit gold mines (SIC 0611) employing 468 people and two open pit iron ore mines (SIC 0617) employing 388 people in Ontario. The main air emission from these mines is particulate matter generated by mining operations and transportation of ores and overburden. The nature of activities in these mines limits the type of controls that can be used. Spraying water to reduce dust generation is now being used. The emissions generated are presented in Table 5.2B.

5.3.2 Food Industry

Air emissions from Ontario's Food Industry were examined for producers of food such as meat, poultry and dairy products, and for restaurants. Four food producing industries and three restaurant categories were examined.

The Meat and Meat Products Industry (SIC 1011) employs over 6,280 people at 117 plants. The main air emissions generated by this industry are odours, VOCs, and particulates. Odours are controlled by scrubbers or incinerators and good housekeeping at slaughter houses, rendering plants and processing plants. The major source of particulate emissions are smoke houses which are controlled by staged fume filters.

The Poultry Products Industry (SIC 1012) is similar to the Meat Products Industry and is controlled in a similar manner. It employs over 4,100 people in 32 plants.

The Commercial Fish Products Industry (SIC 1021) is a small part of Ontario's Food Industry. About 3,000 people work in 17 plants. A vast amount of the commercial fish is filleted and flash frozen for export. Air emissions consist primarily of uncontrolled particulates released when fish is smoked.

There are over 3,600 employees at the 94 plants that comprise the Other Dairy Products Industry (SIC 1049). The industry produces many products, but not all of the processes used produce air emissions. The major contributor to air emissions are:

- the whey produced as a by-product of cheese and butter production; particulate from the production of skim milk powder; and the water vapour created when evaporated milk is made.

  Small producers of cheese may not control the odours created by whey, while larger producers use scrubbers. The milk particulate generated by skim milk powder is controlled by baghouses and the water vapour from milk evaporation is controlled with mist eliminators.

The second group within the food industry is the restaurants (SIC 9211, 9212, 9213). It is estimated that 75,000 work in 15,000 restaurants and fast food outlets. These three SIC categories can be considered the same because they all emit the same contaminant: odours. Some particulate fume is discharged from charcoal broiling. Industry characteristics and emissions are presented in Tables 5.3A and 5.3B.

5.3.3 Pulp and Paper and Allied Products

The Ontario Pulp and Paper and Allied Products Industry comprises two distinct groups of industries. The first group produces pulp, kraft paper, newsprint and paperboard. The second group produces offset printed matter of different types and the services they require, such as type setting, plate making and binding.

Kraft Pulp Mills (SIC 2711) employ over 3,600 people at nine plants. The major sources of air emissions are recovery boilers and lime kilns which emit particulate matter and carbon monoxide. Chlorine and chlorine dioxide are emitted by bleach plants.

These mills control their air emissions with a variety of control technologies, including electrostatic precipitators, scrubbers and multi-clones.

Newsprint Mills (SIC 2712) employ a total of 8,400 people at 11 plants. They emit particulates, acid gases and some carbon monoxide. The Kraft mill components also emit chlorine and chlorine dioxide.

The third part of the pulp and paper group of industries are the Paperboard Mills (SIC 2713). There are three types of paperboard mills. The first, with kraft pulping, employs 1,154 people at two plants. As with previous kraft pulping mills, the recovery boiler and the lime kiln are the major sources of carbon monoxide and particulate matter emitted to the air. Chlorine compounds are emitted from the bleach plant.

The second type of mill uses semi-chemical pulping. There is one such plant employing 200 people. The main emission is uncontrolled particulate matter from its steam boiler.

The final type of paperboard mill has over 1,300 employees at 13 plants. The major sources of air emissions are the steam boilers which emit uncontrolled particulate matter.

The second group of industries to be discussed in this sector produces offset printing. The major emissions from them are volatile organic compounds (VOCs).

The Business Forms Industry (SIC 2811) is made up of 44 plants, employing over 5,400 people. The industry emits uncontrolled VOCs into the air.

There are 15,755 people employed in 358 plants of the Other Commercial Printing Industry (SIC 2819). Air emissions from this industry are not controlled.

About one third of the Plate Making, Type Setting and Binding Industry (SIC 2821) has no controls, while two thirds use catalytic incineration. This industry has 130 plants employing slightly more than 8,000 employees.

The Magazine and Newspaper Industry (SIC 2841) has approximately 10,000 employees at 82 plants. Half the firms emit uncontrolled VOCs, while the other half have catalytic incinerators.

The study examined the wallpaper component of the Other Combined Publishing, Printing Industry (SIC 2849). One firm used thermal incinerators to control their VOC emissions while ten firms were uncontrolled. This industry has 11 plants and 628 employees.

Details on process characteristics and emissions are provided in Tables 5.4A and 5.4B.

5.3.4 Iron and Steel Industry

The Ontario Iron and Steel Industry sector employs more than 51,000 people in 34 plants and is made up of three parts. The first part, Ferroalloy (SIC 2911), produces special alloys that are added to steel to improve its strength and durability. This sector is small (one plant with 20 employees) and uses exothermic ovens which produce negligible air emissions.

The second part, steel foundries (SIC 2912) employs close to 49,000 people in 24 plants. It first produces iron and then steel by manufacturing and then mixing coke with iron ore in open hearth furnaces. The steel is made in basic oxygen furnaces and formed or cast into slabs, or ingots. The major air emissions that are produced and controlled are particulates. A variety of controls are used including electrostatic precipitators, baghouses and scrubbers.

The third part, (SIC 2919) with nine plants and 2254 employees, produces speciality and other steels and includes electric arc furnaces. Scarfing, cooling pits, forming operations and boiler emissions are included in this category.

The characteristics of the industries and the emissions produced are provided on Tables 5.5A and 5.5B. The coking operations produce VOCs. According to information obtained, some VOCs are controlled, but others are not. There was inadequate information available to quantify these emissions and therefore they are not shown on the tables. VOCs would be subject to control under the proposed revisions to Reg. 308.

5.3.5 Foundry Industries

Ontario foundries employ approximately 14,000 people at 147 plants. The industry is divided into three SIC categories but the processes used by each are similar. Metal is melted and poured into molds (casting) and manipulated by mechanical means into a desired shape.

Particulate matter is the primary air emission in the melting, pouring, casting and cleaning processes. The casting process includes making and baking sand and other materials into molds. When the cooled casting is removed from the mold, the old material is recycled or discarded and some emissions are created. The casting and formed products are finished by grinding and machining, operations that produce low emissions. Emissions from about half of the processes are uncontrolled. The other half are controlled by afterburners, scrubbers and baghouses. VOC emissions are released from painting of finished castings.

The characteristics of the industries in this sector and their emissions are provided in Tables 5.6A and 5.6B.

5.3.6 Non-Ferrous Smelters and Refiners

There are approximately 4,900 people working in 16 plants that make up Ontario's Non-Ferrous Smelters and Secondary Refineries Industry (SIC 2959). This study examined two aspects of the industry, non-ferrous raw ore processors and non-ferrous metal recyclers. The raw ore processors mine ores which are converted into metal using combinations of mechanical, chemical or electrolytic steps. It is these conversion steps that release contaminants into the atmosphere. The main contaminants are particulate matter which include metals such as iron, copper and nickel, and gases. The recycling industry releases particulate which contains heavy metals such as lead.

The gases from specific primary smelters are covered by separate regulations: for INCO - O. Reg. 660/85 Inco Sudbury Smelter Complex - 1994; and for Falconbridge - O. Reg. 661/85 Falconbridge Smelter Complex - 1994. Therefore, the gases from primary non-ferrous smelters were not included in this study. Gases from the lead recycling industry are not controlled.

The type of control device used by the industry depends on the contaminant to be controlled and its source. Controls in common use include baghouses, electrostatic precipitators and cyclones for particulate matter and metals, and scrubbers for acidic gases and odours.

Industry characteristics and emissions are provided in Tables 5.7A and 5.7B.

5.3.7 Automotive Industry

This study identified the industrial processes that are the main sources of air emissions from Ontario's Automotive Industry. The major emissions are: VOCs from the painting operations in the industry (SIC 3231); particulates generated in the production of steering and suspension parts (SIC 3254); asbestos from brake linings (SIC 3255); particulates from aluminum wheel production (SIC 3255); and lead emitted when wet cell automotive batteries are manufactured (SIC 3259).

Emissions from SIC category 3244 covering truck and bus bodies, commercial trailer bodies, non-commercial trailer bodies and mobile homes were included in SIC 3231. Emissions from motor vehicle engines and engine parts manufacturing (SIC 3251) were included with foundry emissions (SIC 2941) since these manufacturing processes are often carried out at the large automotive foundries.

Industry characteristics and emissions are provided in Tables 5.8A and 5.8B.

5.3.8 The Inorganic Chemical Manufacturing Industry

The Inorganic Chemical Manufacturing Industry in Ontario is made up of a number of industries which employ over 10,400 people at 200 plants. Industries were examined separately because they do not have common production processes.

The Domestic Clay Industry (SIC 3571) employs 786 people at 27 plants. The industry produces baked clay products, primarily bricks. All nine plants use baghouses to control the major air emission, particulate matter. One plant uses a dry lime scrubber to control air emissions from its tunnel kiln; the eight other kilns are not controlled. The dryers are not controlled.

The Imported Clay Industry (SIC 3512) employs 1,056 people at 51 plants. Firms use baghouses, scrubbers and water wash booths to control the emission of particulates, the main air emission from the industry.

The Cement Industry (SIC 3521) employs 1,237 people at eight plants. Cement production involves the combining and transformation of dried ingredients into a variety of cements. Combustion of oil and gas in kilns produces emissions of sulphur dioxide and nitrogen oxides. Particulates are released when dry ingredients are combined or transferred. The air emissions from all processes are controlled primarily by electrostatic precipitators and baghouses.

There are 25 plants employing 1,467 people in the Abrasives Industry (SIC 3571) producing silicon carbide, aluminum oxide and zirconium alundum. The main air emissions are sulphur dioxide, controlled by incineration and particulate matter controlled by baghouses.

Lime production (SIC 3581) is carried out at nine plants, employing 430 people. Particulate matter emissions are generated in the crushing, conveying and storing of lime powder. The particulates are controlled by a variety of control devices including electrostatic precipitators, watersprays, cyclones and baghouses.

The General Inorganic Chemicals Industry (SIC 3711) employs 5,246 people at 67 plants. These plants produce a range of products using a variety of chemical reactions. This study has grouped selected chemicals by the type of device used to control air emissions. The major air emissions are ammonia, particulates, VOC and hydrocarbons. The controls used include baghouses, scrubbers of different types, incineration and catalytic reduction. Some processes with low emissions emit contaminants directly into the atmosphere.

The final industry in this sector is the Chemical Fertilizer Industry (SIC 3721) which employs 213 people at 13 plants. The industry mixes dry chemicals together to produce fertilizers and in the process releases emissions of chemical particulate matter. These emissions are usually controlled with a combination cyclone and baghouse system.

The characteristics and emissions from industries in this sector are provided in Tables 5.9A and 5.9B.

5.3.9 Petroleum Refining Industry

The petroleum refining industry in Ontario (SIC 3611) employs 2122 people at seven refineries. The major pollutant, sulphur dioxide, is produced by the combustion of fuel in boilers and heaters during the refining process and from specific processes such as cracking and sulphur removal.

The industry uses a variety of controls to suit the special conditions of producing, storing and transferring petroleum distillates. These controls include low sulphur fuels, two-stage combustion, floating roofs on storage tanks, vapour conservation systems, sulphur recovery plants and cyclones and electrostatic precipitators for particulate control.

Industry characteristics and emissions are provided in Tables 5.10A and 5.10B.

5.3.10 Asphalt Paving Industry

The Asphalt Paving Industry in Ontario (SIC 3699) employs 1240 people at 150 plants. There are two plant types: permanent (83% of the industry) and portable (17% of the industry). The primary air emission from both types of plants is particulates; gaseous and organic emissions are also released but they are not controlled. To control particulates, the permanent plants use baghouses while 80% of the portables use venturi scrubbers and 20% use baghouses.

Paving Industry characteristics and emissions are provided in Tables 5.11A and 5.11B.

5.3.11 Petrochemical Products Industry

The Petrochemical Products Industry in Ontario includes a large number of firms, using a variety of processes, employing many types of air emission controls. This sector employs about 40,000 people in over 1,600 plants.

The Organic Chemical Industry (SIC 3712) has 37, employs almost 9,300 people and produces a range of chemicals that are used by other industries or are sold as finished products.

The primary air emissions are VOCs, nitrogen oxides and particulates. These emission are abated by controls that include different types of strippers, adsorbers, incinerators, baghouses and low nitrogen oxide burners.

The Plastic and Synthetic Resin Industry (SIC 3731) combines organic and synthetic resins to form a variety of products. There are 80 plants employing 5,200 people. The primary air emission, styrene, a VOC, is uncontrolled. Dispersion is used to reduce styrene concentrations to acceptable levels. Emissions from plastic manufacturing processes are small.

The Paint and Varnish Industry (SIC 3751) employs over 5500 people in 98 plants. The major air emissions from paint manufacturing are VOC's released from the solvents used in paints and varnishes, and particulate matter, released when pigments are conveyed, mixed and packaged. Pigments are controlled with a baghouse. Varnish cooking releases VOCs, which are not controlled.

Approximately 1300 people work in 40 plants producing primary ink (SIC 3791). The major air emission is VOCs which may come from uncontrolled sources or sources controlled by condensers or venturi scrubbers. Baghouses are used for particulate matter control.

The major air emissions from the Solvent Based Adhesive Industry (SIC 3792) are VOCs. This industry employs 600 people 43 plants. The existing control systems use condensers and carbon filters.

The "Other Chemicals" (SIC 3799) category of the industry contains 155 plants that employ over 6,000 people. This broad grouping includes producers of metallic additives for fuels who use baghouses to control heavy metal emissions; plasticizer producers who emit uncontrolled nitrogen oxides; acrylic paint pigments manufacturers who use adsorbers to control VOC emissions and solvent reclaimers who emit uncontrolled VOCs.

The final part of the petrochemical industry sector, the dry cleaning industry (SIC 9721), employs 12,000 people in 1,200 plants. About two thirds of the plants use a solvent recovery system that emits solvents; the balance use a totally enclosed system with no VOC emissions.

Industry characteristics and emissions are provided in Tables 5.12A and 5.12B.

5.3.12 Electric Power Generation

The study examined six fossil-fuel Ontario Hydro electric power generating stations employing 1,986 people (SIC 4911). These stations fill the need for peak electrical power and burn oil, bituminous coal and lignite coal. Since the major air emission is particulate matter, all these stations use electrostatic precipitators as control devices. Gaseous emissions are controlled by a specific regulation - O. Reg. 281/87, Ontario Hydro - and were not included in this study.

Generating station characteristics and emissions are provided in Tables 5.13A and 5.13B.

5.3.13 Waste Disposal Industry

The Waste Disposal Industry (SIC 4999) includes landfill sites, municipal waste transfer stations and incinerators, sewage sludge incinerators, privately operated incinerators and hospital waste incinerators. This diverse group of waste disposal methods employ an equally diverse group of air emission control technologies.

Transfer Stations

The 13 transfer stations in Ontario emit some odours into the air. These odours are controlled by "ad hoc" spraying with a deodourizer.

Landfill

Landfill sites can be categorized by their type of air emission control. Thirty-seven sites have no control or passive controls, six have active ventilation and four have gas recovery systems and incineration. The primary air emissions from landfill sites are methane and reactive organic gases (ROG).

Municipal Incinerators

There are two municipal incinerators in operation; one is a semi-suspension and one is a multi-chamber incinerator. The main emissions from semi-suspension incinerators are acid gases, particulate matter and heavy metals, and organic compounds. The air emissions are controlled using quench towers and baghouses. Primary air emissions from multi-chamber incinerators are particulates, heavy metals, organics and acid gases. All are controlled by a conditioning tower, lime injection, and baghouse.

Sewage Sludge Incinerator

There are three fluidized bed and two multi-hearth sludge incinerators in Ontario. The emissions include particulates, heavy metals, hydrocarbons, acid gases and organics.

The emission control equipment used by the different sewage sludge incinerators varies. The three fluidized bed incinerators use venturi scrubbers to abate air emissions. One multi-hearth incinerator uses a wet scrubber; the other uses a scrubber and mist eliminator to control air emissions.

Private Waste Disposal

Three commercial and industrial incinerators were examined in this study. These incinerators burn rubbish that is generated on their premises and other selected waste. All three use lime injection and baghouses to reduce their gaseous and particulate air emissions.

Institutional Waste Disposal

The 100 hospital incinerators in Ontario burn hazardous materials that would not be accepted at other disposal sites. Combustion occurs at very high temperatures to destroy pathological waste and is quite complete.

Waste disposal and incineration characteristics and emissions are provided in Tables 5.14A and 5.14B.

References - Chapter 5

Austin, George, T., 1984. *Shreve's Chemical Process Industries.* Fifth Edition, Toronto: McGraw-Hill Book Company.

The Canadian Chemical Producers' Association, 1983. *The Canadian Chemical Industry: A Fact Book.* Summer, Ottawa.

The Canadian Chemical Producers' Association, 1987. *1986 Sector Up-Date Reports, Ottawa.*

The Canadian Chemical Producers' Association, 1987. *Company Profiles.* November 1987, Ottawa.

Carr, R.C., 1983. *Second Conference on Fabric Filter Technology for Coal-Fired Power Plants".* Conference Summary, Journal of the Air Pollution Control Association, October, Volume 33 (10), Pg. 949-954.

Chemicals Directorate - Department of Regional Industrial Expansion, 1987. *Canadian Chemical Register 1986/87.* June, Ottawa.

Constance, John D., 1986. *Controlling In-Plant Airborne Contaminants: System Design and Calculations.* New York: Marcel Dekker, Inc.

Dunbar, D., and Rust, G., 1985. *BACT/LAER (Best Available Control Technology/Lowest Achievable Emission Rate).* Clearinghouse: A Compilation of Control Technology Determinations: Volume II- C, Appendix G - Source Type Codes 8-12. EPA Report No. EPA-450/3-85-016D.

Environment Canada, 1986. *Environment Status Report 1979-1984 - Vinyl Chloride Industry.* September, Ottawa.

Gallagher and Associates, 1988. *The Foundry Industry in Ontario and Outlook for Industrial Minerals.* Ontario Ministry of Northern Development and Mines, Industrial Mineral Background Paper 7, 44 p, Queen's printer for Ontario.

Geadah, M. 1987. *Environmental Status Report for the Canadian Petroleum Refining Industry 1983-1984.* Environment Canada, Ministry of Supply and Services Canada.

Health and Welfare Canada, 1987. *Benzene.* November, Ottawa.

Kinsey, J.S., 1986. *Asphaltic Concrete Industry Particulate Emissions Source Category Report.* Prepared for U.S. EPA under contract #68-02-3158. 108 pp plus Appendices.

Motor Vehicle Manufacturers' Association, 1987. *Facts and Figures of the Automotive Industry in Canada.* Northern Miner Press, 1987-88. Canadian Mines Handbook.

Ontario Ministry of Industry, Trade and Technology, 1987. *Made in Ontario/Canada.* Queen's Printer for Ontario.

Ozvacic, V., 1982. *Sudbury Environmental Study, Emissions of Sulphur Dioxides, Particulates and Trace Elements in the Sudbury Basin.* Ministry of the Environment, October.

SENES Consultants Limited, 1987. *Report and Recommendations of a Provincial Officer Pursuant to the Environmental Protection Act, R.S.O. 1981, Section 126.* March.

Smith, R.C. and Daley, M.R., 1987. *Domestic Secondary Lead Industry: Production and Regulatory Compliance Costs.* U.S. Dept. of the Interior, Bureau of Mines. Information Circular 9156, 18 pp.

Statistics Canada, 1985. *Manufacturing Industries of Canada: National and Provincial.* Ottawa: Ministry of Supplies and Services Canada.

Steiner, B.A. and Roffman, A., 1981. *Air Pollution Control in the Iron and Steel Industry.* Selected Papers from an APCA Specialty Meeting, Introduction, Journal of the Air Pollution Control Association, October, Volume 31, No (10), Pg. 1053-1066.

United States Environmental Protection Agency (U.S. EPA), 1985. *Compilation of Air Pollutant Emission Factors Volume 1: Stationary Point and Area Sources.* AP-42, 4th Edition. Office of Air Quality, Planning and Standards.

United States Environmental Protection Agency (U.S. EPA), 1986. *Compilation of Air Pollution Emission Factors* Vol. 1. Stationary Point and Area Sources, AP-42 Supplement A, October 1986.

TABLE 5.1

SIC CATEGORIES AND PROCESSES CONSIDERED

	(1) S.I.C.	(3) Information obtained on the following number of processes	(4) Information reported on the following number of processes
	Open Pit Mining		
1	0611	1	1
2	0612	n/a	n/a
3	0613	n/a	n/a
4	0614	n/a	n/a
5	0616	n/a	n/a
6	0617	1	1
	Food & Rendering		
7	1011	3	3
8	1012	3	3
9	1021	1	1
10	1041	1	neg.
11	1049	1	1
12	9211	1	(as 9212)
13	9212	1	1
14	9213	1	(as 9212)
	Pulp & Paper		
15	2711	5	5
16	2712	10	10
17	2713	7	7
18	2811	1	1
19	2819	1	1
20	2821	1	1
21	2841	1	neg.
22	2849	2	2
	Iron & Steel		
23	2911	1	1
24	2912	14	14
25	2919	3	2
	Foundries		
26	2941	1	1
27	2971	1	1
28	2999	2	2

TABLE 5.1 (cont'd)

	(1) S.I.C.	(3) Information obtained on the following number of processes	(4) Information reported on the following number of processes
	Non-Ferrous Smelters		
29	2959	2	2
	Automotive Industry		
30	3231	1	1
31	3241	1	-
32	3242	1	-
33	3243	(as 3231)	(as 3231)
34	3244	(as 3231)	(as 3231)
35	3251	1	(as 2941)
36	3252	1	neg.
37	3253	1	(as 3231)
38	3254	1	1
39	3255	2	2
40	3256	1	neg.
41	3257	1	neg.
42	3259	1	1
	Inorganic Chemicals		
43	3511	5	5
44	3512	2	2
45	3521	7	7
46	3571	2	2
47	3581	6	6
48	3711	9	9
49	3721	1	1
	Petroleum Refining Industry		
50	3611	6	6
	Ashphalt Paving Industry		
51	3699	2	2
	Petrochemical Products		
52	3712	6	6
53	3731	1	1
54	3751	2	2
55	3791	1	1
56	3792	1	1
57	3799	4	4
58	9721	2	2
	Electric Power Generation		
59	4911	3	3
	Waste Disposal Industry		
60	4999	10	10

TABLE 5.2A

OPEN PIT MINING
GENERAL CHARACTERISTICS

SIC	Mine Type	Existing Control System	No. of Pits	Number of Employees	Annual Production (tonnes)
0611	Gold	Water Spray	4	468	2,103,800
0617	Iron Ore	Water Spray	2	388	1,099,000
Total Open Pit Mining			6	856	3,202,800

TABLE 5.2B

OPEN PIT MINING

EMISSION GENERATION

SIC	Mine Type	Particulate Emissions per Year at Rated Capacity (tonnes)
0611	Gold	4,418
0617	Iron	2,857

TABLE 5.3A

FOOD INDUSTRY
GENERAL CHARACTERISTICS

SIC Code & Manufacturing Processes	Existing Control System	No. of Plants	No. of Employees	Annual Production (tonnes)
1011 - Meat & Meat Products				
Slaughter Houses	Scrubber	26	1,127	527,542
Rendering	Scrubber	6	260	168,900
Processing (Smoking)	Baghouse	85	4,896	35,000
1012 - Poultry & Poultry Products				
Slaughter Houses	UC	28		240,441
Rendering	UC		3,588	80,147
Processing	UC	4	552	8,015
1021 - Fish Products				
Processing	UC	17	3,000	227
1049 - Other Dairy Products				
Cheese	Scrubber			107,529
Skim Milk Powder	Baghouse			13,983
Evaporated Milk	Mist Eliminator	94	3,612	22,382
9211, 9212, 9213 Restaurants	UC	15,000	75,000	NA
Total Food Industry		15,260	92,035	1,204,166

TABLE 5.3B

FOOD INDUSTRY
EMISSION GENERATION

SIC Code & Manufacturing Processes	Organic Particulates (tonnes)	VOCs (tonnes)	Odour Units (ou/min/facility)
1011 - Meat & Meat Products			
Slaughter Houses			14.3×10^9
Rendering			14.3×10^9
Processing	5.25	6.3	
1012 - Poultry & Poultry Products			
Slaughter Houses			
Rendering			1.7×10^9
Processing	1.2	1.4	
1021 - Fish Products Processing	.1	.1	
1049 - Other Dairy			
Cheese	19.6		
9211, 9212, 9213 Restaurants			5.8×10^9

TABLE 5.4A

PULP AND PAPER AND ALLIED PRODUCTS
GENERAL CHARACTERISTICS

SIC Code & Manufacturing Processes	Existing Control System	Number of Plants	Number of Employees	Product Production at Capacity (tonnes/yr)
2711 - Kraft Pulp Mills		9	3,652	946,200 pulp
. Recovery Boiler	ESP			
. Lime Kiln	Venturi Scrubber			
. Smelt Dissolving Tank	Wet Scrubber			
. Steam Boilers	Multi-clones			
. Bleach Plant	Wet Scrubber			
2712 - Newsprint Mills w/Kraft Pulp		3	3,040	800,000 newsprint 1,107,000 pulp
. Recovery Boiler	ESP			
. Lime Kiln	Venturi Scrubber			
. Small Tanks	Wet Scrubber			
. Steam Boilers	Multiclones			
. Bleach Plant	Wet Scrubber			
- Newsprint Mills w/Sulphite Pulping		2	1,130	460,000 newsprint 470,000 pulp
. Blowpit Stack	Scrubber			
. Acid Plant	Caustic Scrubber			
. Steam Boilers	Multiclones			

TABLE 5.4A (Continued)

SIC Code & Manufacturing Processes	Existing Control System	Number of Plants	Number of Employees	Production at Capacity (tonnes/yr)
- Newsprint Mills w/Groundwood Pulping		2	1,180	450,000 newsprint 450,000 pulp
. Steam Boilers	UC			
- Newsprint Mills		4	3,085	1,195,00 newsprint
. Steam Boilers	UC			
Sub-total (2712)		11	8,435	2,905,000 paper 2,027,000 pulp
2713 - Paperboard Mills w/Kraft Pulping		2	1,154	587,000 paperboard 323,000 pulp
. Recovery Boiler	ESP			
. Lime Kiln	Venturi Scrubber			
. Smelt Tank	Wet Scrubber			
. Steam Boilers	Multiclones			
. Bleach Plant	Wet Scrubber			
- Paperboard Mills w/ Semi-Chemical Pulping		1	200	68,000 paperboard 51,000 pulp
. Steam Boilers	UC			
- Paperboard Mills		13	1,317	751,000 paperboard
. Steam Boilers	UC			
Sub-total (2713)		16	2,671	1,406,000 paperboard 374,000 pulp

TABLE 5.4A (Continued)

SIC Code & Manufacturing Processes	Existing Control System	Number of Plants	Number of Employees	Production at Capacity (tonnes/yr)
2811 - Business Forms Industry	UC	44	5,438	15,825 ink
2819 - Other Commercial Printing Industry	UC	358	15,755	4,861 ink
2821 - Plate Making, Type Setting and Binding Industry	33% UC 66% Catalytic Incineration	130	8,093	4,300 VOCs
2841 - Magazines and Newspaper Industry	50% UC 50% Catalytic Incineration	82	10,098	98,288 ink
2849 - Other Combined Publishing Printing Industry				
. Wallpaper	Thermal Incineration	1	225	2,880 ink
. Other	UC	10	403	5,160 ink
Total Pulp and Paper and Allied Products		661	54,770	

TABLE 5.4B

PULP AND PAPER AND ALLIED PRODUCTS
EMISSION GENERATION

SIC Code & Manufacturing Processes	Emission (tonnes/yr)						
	PM	SO_2	NO_x	CO	Cl_2	ClO_2	VOC's
2711 - Kraft Pulp Mills							
. Recovery Boiler	5,097	3,227	747	1,088	0	0	
. Lime Kiln	1,538	85	590	3,638	0	0	
. Smelt Dissolving Tank	171	27	0	0	0	0	
. Steam Boilers	87	6,391	1,532	1,648	0	0	
. Bleach Plant	0	0	0	0	567	189	
2712 - Newsprint Mills w/Kraft Pulp							
. Recovery Boiler	3,377	2,434	496	692	0	0	
. Lime Kiln	1,014	103	392	2,280	0	0	
. Smelt Dissolving Tank	112	34	0	0	0	0	
. Steam Boilers[1]	102	1,594	1,223	1,734	0	0	
. Bleach Plant		0	0	0	164	221	
- Newsprint Mills w/Sulphite Pulping							
. Blowpit Stack	0	230	0	0	0	0	
. Acid Plant	0	92	0	0	0	0	
. Steam Boiler	216	330	216	562	0	0	

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[1] Pro-rated from PM for 2711 Boilers.

TABLE 5.4B (Continued)

SIC Code & Manufacturing Processes	Emission (tonnes/yr)						
	PM	SO_2	NO_x	CO	Cl_2	ClO_2	VOC's
- Newsprint Mills w/Groundwood Pulping							
. Steam Boilers	682	2,231	355	1,378	0	0	
- Newsprint Mills							
. Steam Boiler	1,120	5,660	1,120	1,650	0	0	
2713 - Paperboard Mills w/Kraft Pulping							
. Recovery Boiler	3,704	1,234	469	740	0	0	
. Lime Kiln	1,110	37	370	2,470	0	0	
. Smelt Tank	62	12	0	0	0	0	
. Steam Boilers	304	91	252	493	0	0	
. Bleach Plant	0	0	0	0	81	2	
- Paperboard Mills w/ Semi-Chemical Pulping							
. Steam Boilers	48[1]	14	44	11	0	0	
- Paperboard Mills							
. Steam Boilers	340	10	107	30	0	0	

[1] Based on Newsprint Mill Boilers.

TABLE 5.4B (Continued)

SIC Code & Manufacturing Processes	Emission (tonnes/yr)						
	PM	SO_2	NO_x	CO	Cl_2	ClO_2	VOC's
2811 - Business Forms Industry							6,330
2819 - Other Commercial Printing Industry							3,646
2821 - Plate Making, Type Setting and Binding Industry							490
2841 - Magazines and Newspaper Industry							38,701
2849 - Other Combined Publishing Printing Industry							
. Wallpaper							0.2
. Other							3,095.0

TABLE 5.4B

PULP AND PAPER AND ALLIED PRODUCTS
EMISSION GENERATION

SIC Code & Manufacturing Processes	Emission (tonnes/yr)						
	PM	SO_2	NO_x	CO	Cl_2	ClO_2	VOC's
2711 - Kraft Pulp Mills							
. Recovery Boiler	5,097	3,227	747	1,088	0	0	
. Lime Kiln	1,538	85	590	3,638	0	0	
. Smelt Dissolving Tank	171	27	0	0	0	0	
. Steam Boilers	87	6,391	1,532	1,648	0	0	
. Bleach Plant	0	0	0	0	567	189	
2712 - Newsprint Mills w/Kraft Pulp							
. Recovery Boiler	3,377	2,434	496	692	0	0	
. Lime Kiln	1,014	103	392	2,280	0	0	
. Smelt Dissolving Tank	112	34	0	0	0	0	
. Steam Boilers[1]	102	1,594	1,223	1,734	0	0	
. Bleach Plant		0	0	0	164	221	
- Newsprint Mills w/Sulphite Pulping							
. Blowpit Stack	0	230	0	0	0	0	
. Acid Plant	0	92	0	0	0	0	
. Steam Boiler	216	330	216	562	0	0	

[1] Pro-rated from PM for 2711 Boilers.

TABLE 5.4B (Continued)

SIC Code & Manufacturing Processes	Emission (tonnes/yr)						
	PM	SO_2	NO_x	CO	Cl_2	ClO_2	VOC's
- Newsprint Mills w/Groundwood Pulping							
. Steam Boilers	682	2,231	355	1,378	0	0	
- Newsprint Mills							
. Steam Boiler	1,120	5,660	1,120	1,650	0	0	
2713 - Paperboard Mills w/Kraft Pulping							
. Recovery Boiler	3,704	1,234	469	740	0	0	
. Lime Kiln	1,110	37	370	2,470	0	0	
. Smelt Tank	62	12	0	0	0	0	
. Steam Boilers	304	91	252	493	0	0	
. Bleach Plant	0	0	0	0	81	2	
- Paperboard Mills w/ Semi-Chemical Pulping							
. Steam Boilers	48[1]	14	44	11	0	0	
- Paperboard Mills							
. Steam Boilers	340	10	107	30	0	0	

[1] Based on Newsprint Mill Boilers.

TABLE 5.4B (Continued)

SIC Code & Manufacturing Processes	PM	SO_2	NO_x	CO	Cl_2	ClO_2	VOC's
	Emission (tonnes/yr)						
2811 - Business Forms Industry							6,330
2819 - Other Commercial Printing Industry							3,646
2821 - Plate Making, Type Setting and Binding Industry							490
2841 - Magazines and Newspaper Industry							38,701
2849 - Other Combined Publishing Printing Industry							
. Wallpaper							0.2
. Other							3,095.0

TABLE 5.5A

IRON AND STEEL INDUSTRY
GENERAL CHARACTERISTICS

SIC Code & Manufacturing Processes	Existing Control System	Number of Plants	Number of Employees	Annual Production at Capacity (tonnes)
2911 Ferroalloy				
. Exothermic	Scrubber	1	20	1,350
2912 Steel Foundries				
. Coke Plants	ESP/Baghouse Scrubber			- -
. Blast & Open Hearth Furnace	Baghouse/ Scrubber			- -
. Roof Monitors	No Control			-
. Basic Oxygen Furnace	Baghouse/Scrubber			-
Sub Total: Steel Foundries		24	48,925	12,686,200
2919 Other Primary Steel				
. Electric Arc	Baghouse	5		1,977,500
. Boilers Scarfing Pits	UC	4		12,686,200
Sub Total: Other Primary Steel		9	2,254	14,663,700
Total Iron & Steel Industry		34	51,199	27,351,250

TABLE 5.5B

IRON AND STEEL INDUSTRY
EMISSION GENERATION

SIC Code & Manufacturing Processes	Annual Emissions at Rated Capacity (tonnes) Particulates
2911 Ferroalloy . Exothermic	19.0
2912 Steel Foundries	
. Coke Plants	
- Charging	623.7
- Pushing	123.1
- Quenching	764.9
- Flue Stacks	1234.4
. Blast & Open Hearth Furnace	
- Melting	547.0
- Heating	63.4
- Dekishing	53.7
- Desulphuring	153.5
- Fugitive Emissions	1069.4
. Basic Oxygen Furnace	
- Charging	1067.0
- Tapping	30.4
- Transfer	26.6
- Melting & Refining	316.0
- Fugitive Emissions	2749.0
2919 Other Primary Steel	
. Electric Arc	306.5
. Boilers Scarfing & Pits	253.7

TABLE 5.6A

FOUNDRIES
GENERAL CHARACTERISTICS

SIC Code & Manufacturing Process	Existing Control System	Number of Plants	Number of Employees	Annual Production at Capacity (tonnes)
2941 Iron Foundries	Afterburner/ 58% with baghouse/ remainder scrubber	61	7,600	1,584,180
2971 Copper and Brass Works	25% UC Remainder Baghouse	23	2,250	78,400
2999 Rolled Casting				
. Copper	UC	63	4,283	13,529
. Aluminum	UC			62,000
Total Foundries		147	14,133	1,738,109

TABLE 5.6B

FOUNDRIES
EMISSION GENERATION

SIC Code & Manufacturing Process	Annual Emissions at Rated Capacity (tonnes)	
	Particulates	VOCs
2941 Iron Foundries	11,406	
2971 Copper and Brass Works	305	
2999 Rolled Casting		
. Copper	92	
. Aluminum	186	2.5

TABLE 5.7A

NON-FERROUS SMELTERS & REFINERIES
GENERAL CHARACTERISTICS
(SIC 2959)

Plant Types	Existing Control Systems	No. of Plants	No. of Employees	Annual Production at Capacity (tonnes)
Primary Smelters	Cyclone ESP Wet ESP Dry Baghouse Scrubbers Stacks	13		738,387
Secondary Lead Smelters	Baghouse Wet scrubber Mist Eliminator	3		90,936
Industry Totals		16	4,983	829,323

TABLE 5.7B

NON-FERROUS SMELTERS & REFINERIES
EMISSION GENERATION
(SIC 2959)

Plant Type	Annual Emissions at Rated Capacity (tonnes)	
Primary Smelters	PM	15,434
	Iron	1,901
	Copper	708
	Nickel	495
	Lead	211
	Arsenic	132
	Zinc	29
Secondary Lead Smelters	PM	60
	Lead	5.9

Table 5.8A

AUTOMOTIVE INDUSTRY
GENERAL CHARACTERISTICS

SIC Code and Manufacturing Processes	Existing control system	Number of plants	Number of employees	Annual production (units)
3231 - automobile and light duty truck surface coating	dispersion	212	125,769	2,162,200 (vehicles)
3254 - steering and suspension	baghouse	32	5,688	98,280 (tonnes)
3255 - brake lining production	baghouse	6	1,230	3,348 (tonnes)
aluminum wheel production	baghouse	1	200	1,000,000 (wheels)
3259 - wet cell automotive battery production	baghouse & packed scrubber	8	548	7,365,120 (batteries)
Total Automotive Industry		259	133,435	

Table 5.8B

AUTOMOTIVE INDUSTRY
EMISSION GENERATION

SIC Code and Manufacturing Processes	Annual Emissions in Tonnes at Rated Capacity				
		Particulates			
	VOC	Lead	Asbestos	Talc	Other
3231 - automobile and light duty truck surface coating	25,730				
3254 - steering and suspension					40.9
3255 - brake lining production			.13		.29
aluminum wheel production				19	
3259 - wet cell automotive battery production		51.1			
TOTALS	25,730	51.1	.13	19	41.19

TABLE 5.9A

INORGANIC CHEMICAL MANUFACTURING INDUSTRY
GENERAL CHARACTERISTICS

SIC Code & Manufacturing Processes	Existing Control System	Number of Plants	Number of Employees	Product Production at Capacity (tonnes/yr)
3511 - Domestic Clay				
. Raw MH	pulse bag	9		1,593,000
. Tunnel kiln oil	none	2		353,965
. Tunnel kiln gas	none	6		1,061,896
. Tunnel kiln gas	dry lime scrubber	1		176,983
. Gas Fired Dryer	none	9		1,593,000
Sub-Total		27	786	1,593,000
3512 - Imported Clay				
. Ceramics	baghouse water wash booth scrubber			
Sub-Total		51	1056	165,517
3521 - Cement				
. Wet Kiln	electrostatic precipitator			3,150,000
. Dry Kiln	electrostatic precipitator			4,725,000
. Clinker Cooler	fabric filter			4,725,000
	gravel bed filter			3,150,000
. Raw Feed Mills	baghouse			7,875,000

TABLE 5.9A (Continued)

SIC Code & Manufacturing Processes	Existing Control System	Number of Plants	Number of Employees	Product Production at Capacity (tonnes/yr)
. Finish Mills	baghouse			7,875,000
. Raw Feed Handling and Storage	baghouse			7,875,000
. Clinker Handling	baghouse			
. Product Mills	baghouse			
. Product Handling and Storage	baghouse			
Sub-Total		8	1237	7,875,000
3571 - Abrasives				
. Aluminum Oxides	baghouse		865	330,100
. Silicon Carbide	baghouse		602	229,200
Sub-Total		25	1467	559,300
3581 - Lime				
. Calcining	electrostatic precipitator	3		
. Product cooler	vent to kiln			
. Crushing and conveying	location in quarry			
stockpiles	water spray			
hydrators	water spray			
Sub-Total		9	430	3,085,000

TABLE 5.9A (Continued)

SIC Code & Manufacturing Processes	Existing Control System	Number of Plants	Number of Employees	Product Production at Capacity (tonnes/yr)
3711 - General Inorganic Chemicals				
. Ammonium Products	none			931,645
. Ammonium Phosphate	cyclone			618,360
. Urea and Carbon Products	baghouse			1,117,825
. Phosphoric Acid	packed tower scrubber			273,050
. Carbon Pellets	thermal incinerator			210,721
. Nitric Acid	catalytic reduction			1,060,534
. Ammonium Nitrate	wet scrubber (63%)			12,662,249
. Ammonium Nitrate	wet scrubber (95%)			13,168,249
. Ammonium Phosphate	venturi scrubber (82.7%)			555,625
Sub-Total		67	5246	16,506,129[a]
3721 - Chemical Fertilizer	cyclone and baghouse	13	213	149,100
Total Inorganic Chemical Manufacturing Industry		200	10,435	29,767,529

Note:

[a] This represents the total production. The values given for the control system groupings may include a certain production value under several different groupings based on production processes.

TABLE 5.9B

INORGANIC CHEMICAL MANUFACTURING INDUSTRY EMISSION GENERATION

SIC Code & Manufacturing Processes	Annual Emissions in Tonnes per Year at Rated Capacity PM	SO_2	VOC	NO_x	CO	F	H_2S	HC	NH_3	Nitric Acid
3511 - Domestic Clay Brick Manufacturing										
. Raw Materials Handling	270									
. Tunnel Kiln (gas)	13		4.7	74	32	425				
. Tunnel Kiln (gas)	2.1		0.8	16	5.3	71				
. Tunnel Kiln (oil)	103	701	5.8	186	21.2	142				
. Gas Fired Dryer	10	876								
3512 - Imported Clay										
. Ceramics	58									
	1,887									
3521 - Cement Industry										
. Wet Kiln	513.0	93,240		10,206						
. Dry Kiln	907	13,860		15,309						
. Clinker Cooler	2438									
	1625									
. Raw Feed Mills & Handling	354									
. Finish Mills	512									
. Materials Handling & Storage	284									
3571 - Abrasives										
. Aluminum Oxide	541									
. Silicon Carbide	376	3,667								

TABLE 5.9B (Continued)

SIC Code & Manufacturing Processes	Annual Emissions in Tonnes per Year at Rated Capacity									
	PM	SO_2	VOC	NO_x	CO	F	H_2S	HC	NH_3	Nitric Acid
3581 - Lime										
. Lime Kiln	1660									
. Product Cooling	0									
. Product Hydration	154									
. Crushing & Grinding	1500									
. Stockpiles	10.5									
. Storage	9.5									
3711 - General Inorganic Chemicals										
. Ammonia Products	684	845		136		3.4		1221	272	
. Ammonium Phosphates	87.2							4.7		
. Urea & Carbon Products	1565	236		111				1453	.022	
. Phosphoric Acid	145					3.3		38		
. Carbon Pellets	844		4846							
. Nitric Acid	136			1781				7.4		
. Ammonium Nitrate	751							113	2412	328
. Ammonium Nitrate	712							266	2450	350
. Ammonium Phosphate	83					22.2		1500	38.3	
3721 - Chemical Fertilizer	1.6									

TABLE 5.10A

PETROLEUM REFINING
GENERAL CHARACTERISTICS
(SIC 3611)

Plant Type	Existing Control	No. of Plants	No. of Employees	Annual Production (tonnes)
Petroleum Refineries	Low S fuel Low NO_x burners Cylones Cyclones & ESP Floating Roof Tanks Two Stage Combustion CO Boilers Sulphur Recovery Plant Vapour Recovery System Safety Blowdown System Off gas Collection	7	2122	29,255,725

TABLE 5.10B

PETROLEUM REFINING EMISSION GENERATION

(SIC 3611)

Source Type	Emission (tonnes/yr)			
	SO_2	NO_x	PM	Hydrocarbon (VOC)
Process Combustion		6,424	2,847	93
Heaters Gas	148			
Heaters Oil	12,410			
Boilers Gas	183			
Boilers Oil	14,600			
Total	28,033			
Catalytic Cracker	9,230	1,424	1,741	
Sulphur Plant Tail Gas	5,475			
Flares, Vents and Off Gas	1,387			
Storage Tanks				1,924
Pumps & Compressors				752

TABLE 5.11A

ASPHALT PAVING INDUSTRY
GENERAL CHARACTERISTICS
(SIC 3699)

Plant Type	Existing Control System	Number of Plants	Number of Employees	Annual Production at Rated Capacity (tonnes)
Permanent	. Baghouse	125	1000	69,600,000
Portable	. Venturi	20	200	12,300,000
	. Baghouse	5	40	2,400,000
TOTALS		150	1240	84,300,000

TABLE 5.11B

ASPHALT PAVING INDUSTRY
EMISSION GENERATION

Plant Type	Total Annual Particulate Emissions Generated by Sector at Rated Capacity (tonnes/year)
Permanent Plants	696
Portable Plants	369
	24
	1089

TABLE 5.12A

PETROCHEMICAL PRODUCTS INDUSTRY GENERAL CHARACTERISTICS

SIC Code & Manufacturing Process	Existing Control System	Number of Plants	Number of Employees	Annual Production at Capacity (tonnes)
3712 Organic Chemical Industry				
PVC	Baghouse & Wet Scrubber Low NO_x Burners			38,421
Vinyl Chloride	Baghouse & Incineration & Low NO_x Burners			82,368
HD/HL Polyethylene Ethylene, Propylene Xylene, Toluene	Baghouse & Carbon Adsorption Incineration & Low NO_x Burners			622,832
Benzene	Carbon Adsorption or Incineration			98,816
Styrene	Steam Stripping & Condenser			35,305
Styrene Acryl Butadiene	Flare or Steam Stripper or Butadiene Adsorber			471
Sub-Total		37	9289	878,213
3731 - Plastics and Synthetic Resins				
Fibreglass Production	Dispersion	80	5200	37,356 laminate

TABLE 5.12A (Continued)

SIC Code & Manufacturing Process	Existing Control System	Number of Plants	Number of Employees	Production at Capacity (tonnes)
3751 - Paint & Varnish				
Paint - Mixing Pigments and Solvents	Baghouse		5119	401,300
Packaging	Baghouse			
Varnish	Uncontrolled		385	30,205
Sub-Total		98	5504	431,505
3791 - Printing Ink				
Solvent	- None - Condenser - Venturi Scrubber			
Pigment Particulate	- Baghouse - Roto-clone (85%)			
Sub-Total		40	1296	63,830
3792 - Adhesive Industries	Condensers and carbon filters	43	600	13,800
3799 - Other Chemicals				
Metallic Additives	Baghouse for Lead			174,760
Plasticizer[1]	None			124,364
Pigment Paint	Adsorber			79,451
Acrylic				121,203
Solvent Reclamation	None			41,752
Sub-Total		155	6082	420,327
SIC 9721 - Dry Cleaning				
Partial Solvent Recovery	Carbon Adsorber	900	9000	27,000 clothing processed

Note:

1. Using plastic to clothes ratio of 1:50.

TABLE 5.12A (Continued)

SIC Code & Manufacturing Process	Existing Control System	Number of Plants	Number of Employees	Production at Capacity (tonnes)
Closed System	No vent to atmosphere	300	3,000	9,000 clothing processed
Sub-Total		1200	12,000	36,000
Total Petrochemical Product Industry		1653	39,971	1,881,031

TABLE 5.12B

PETROCHEMICAL PRODUCTS INDUSTRY
EMISSION GENERATION

SIC Code & Manufacturing Process	Emissions (tonnes/yr)						
	Particulate	SO_2	NO_x	VOC	Styrene	Lead	Perchlorethalenes
3712 Organic Chemical Industry							
PVC	145	0.6	3,842	326			
Vinyl Chloride	1442	1.1	3,684	700			
Organic Gases and Solvents	679.2		158	7,072			
Benzene	34			14			
Styrene	12			1,053			
Styrene Acryl Butadiene	2			26			
SIC 3712 Totals	2,314	1.6	7,684	9,191			
3731 - Plastics and Synthetic Resins					1,307.5		
SIC 3731 Total					1,307.5		
3751 - Paint & Varnish							
Paint - Mixing Pigments and Solvents				1,104			
Packaging	24.1						
Varnish				2,265			
SIC 3751 Total	24.1			3,369			

TABLE 5.12B (Continued)

SIC Code & Manufacturing Process	Emissions (tonnes/yr)						
	Particulate	SO_2	NO_x	VOC	Styrene	Lead	Perchlorethalenes
3791 - Printing Ink							
Solvent - all control types				34.4			
Pigment	19.15						
Particulate	neg.						
SIC 3791 Total	19.15			34.4			
3792 - Adhesive Industries				0.4			
3799 - Other Chemicals							
Metallic Additives						52.4	
Pigment, Acrylics, Sludges	4012						
Plasticizer & Solvent Reclamation			190	9700			
SIC 3799 Total	4012		190	9700		52.4	
SIC 9721 - Dry Cleaning							
Partial Solvent Recovery							50
Closed System							0
SIC 9721 Total							50
Total Petrochemical Product Industry	6370	1.6	7874	22,708	1,308	52.4	50

TABLE 5.13A

ELECTRIC POWER GENERATION
GENERAL CHARACTERISTICS

Station Type	Existing Control System	Number of Employees	Annual Energy Generation (millions of MWh at Rated Capacity)
Bituminous Fired			
. Lakeview	Electrostatic Precipitator	436	21.2
. Lambton	Electrostatic Precipitator	348	17.9
. Nanticoke	Electrostatic Precipitator	592	35.4
Lignite Fired			
. Thunder Bay	Electrostatic Precipitator	159	3.6
. Atikokan	Electrostatic Precipitator	65	2.0
Oil Fired			
. Lennox	Electrostatic Precipitator	386	19.3
	TOTAL	1986	99.4

TABLE 5.13B

ELECTRIC POWER GENERATION
EMISSION GENERATION
(SIC 4911)

Station Type	Annual Particulate Emissions Generated by Plants at Rated Capacity (tonnes)
Bituminous Fired	
. Lakeview	5,130
. Lambton	6,247
. Nanticoke	7,576
Lignite Fired	
. Thunder Bay	500
. Atikokan	300
Oil Fired	
. Lennox	444
TOTAL	20,197

TABLE 5.14A

WASTE DISPOSAL INDUSTRY
GENERAL CHARACTERISTICS
(SIC 4999)

Waste Disposal Facilities	Existing Control Systems	Number of Plants	Number of Employees	Annual Rates Disposal Capacity (tonnes)
Municipal Waste Disposal				
Transfer Stations	None	13	211	1,714,614
Landfill	None & Passive Vent	37	NA	3,400,000
	Active Ventillation	6	NA	1,900,000
	Gas Recovery & Incin.	4	NA	2,900,000
Municipal Waste Incineration				
Semi-suspension Incinerator	Quench & Baghouse	1	NA	150,600
Multichamber Incinerator	Lime Conditioning Tower & Baghouse	1	NA	85,176
Sewage Sludge				
Multihearth Incinerator	Wet Scrubber	1	NA	73,000
	Scrub & Mist Eliminator	1	NA	44,300
Fluidized Bed Incinerator	Venturi Scrubber	3	NA	117,200
Private Waste Disposal				
Commercial & Industrial Incineration	Dry Lime Injection & Baghouse	3	38	81,120
Institutional Waste Disposal				
Hospital Waste Incineration	Not Available	100	NA	95,002
Total Waste Disposal Industry		170		10,561,012

TABLE 5.14B

WASTE DISPOSAL INDUSTRY
ANNUAL EMISSION GENERATION
(SIC 4999)

Waste Disposal Facilities	Odour	PM	Organic Acids	NO_x	CH_4	ROG	SO_2	CO	HC	HCl	Pb	Hg	Cd	Cr	PCDD	PCDF	PCB	Adehydes
							Emission (tonnes/yr)											
Municipal Waste Disposal																		
Transfer Stations	weak																	
Landfill																		
No Control Passive Ventillation					3,298	34												
Active Ventillation					1,843	19												
Gas Recovery & Incineration					58	.87												
Municipal Waste Incineration																		
Semi-suspension Incinerator		240.9		188			307			571	2.4	0.18	1.5	0.6	$1.2x10^{-3}$	$2.3x10^{-3}$	$1.9x10^{-1}$	
Multichamber Incinerator		357.7		102			32			43	0.03	0.01	1.1	0.06	$3.4x10^{-5}$	$5.1x10^{-5}$	0.3	
Sewage Sludge																		
Multihearth Incinerator		152.49		703.8			58.65		58.65	17.6	.9							
Fluidized Bed Incinerator		106.7		146.3			28.4		58.6	17.6	.1							
Private Waste Disposal																		
Commercial & Industrial Incineration		4.9		121.7			40.6	178.5	24.3		0.04	0.2						
Institutional Waste Disposal																		
Hospitals Waste Incineration		108.3	71.25	57.95														46.55

6.0 EMISSION FACTORS AND POTENTIAL CONTROL SYSTEMS

6.1 Introduction

Chapter 6 presents the emission factors and control technologies required to meet alternative abatement levels for the control scenarios outlined in Table 2.2. Each contaminant can be controlled in several ways. Each control method can handle most of the contaminants dependent on operating conditions and reduction wanted.

The information is given in two tables. The first (Table "A") presents the emission factors in kilograms per tonne for existing controls and for successively more stringent controls designated as Levels 3, 2 and 1, with Level 1 being the most stringent.

The major sources of information for these emission factors were; U.S. EPA BACT/LAER clearinghouse publications; Best Available Control Technology reports by South Coast Air Quality management District; and AP-42 Compilation of Emission Factors. Many of the factors were estimated from reported results on recently installed equipment.

The second table (Table "B") presents the control equipment and control systems that could be used in order to meet successive levels of abatement indicated by the emission factors in the first table.

Many control methods (e.g. scrubbers or electrostatic precipitators) are capable of giving different levels of control according to design. For this reason, different emission rates may be indicated in Table A but the control systems as outlined in the corresponding Table B will be the same. Conversely, a change in a control method (e.g. one used to control two pollutants) may result in a change in one emission rate without a change in the other.

Since the various types of emission control systems can usually be designed for a range of efficiencies, they are described, for convenience, as high, medium or low efficiency systems. These are relative terms which vary with their context, but in general they relate to the overall efficiency of contaminant removal. For example, for electrostatic precipitators the range from low to high efficiencies is from less than 85% to over 98%. These terms frequently imply the use of those conditions, such as the pressure drop across a scrubber, which are the major factors governing the efficiency of the system.

In general, low efficiency systems are designed to capture less than 80% of the gases or of particles larger than three microns. High efficiency systems capture over 99% of the materials or of particles less than one micron in size. However, the efficiency of any system is very dependent on the properties of the material being collected.

6.2 Sector Descriptions

In the following sections, the industry emission factors and potential control systems by process are described for each sector.

6.2.1 Open Pit Mining

The control of air emissions from Ontario's Open Pit Mining Industry (SIC 0611 and 0617) depends on dust suppression by using water sprays as needed. At higher levels of control, regular watering and chemical dust suppression would be needed to reduce dust generated primarily from transportation activities.

Aggregate emission factors for mining operations and transportation activities and the proposed controls to achieve them are provided in Tables 6.1A and 6.1B.

6.2.2 Food Industry

Only two of the seven industries that make up the Food Industry in Ontario are using controls on all their processes to reduce air emissions. These are the Meat and Meat Products Industry (SIC 1011) and the Other Dairy Products Industry (SIC 1049). The fish products processing and restaurants including take-out and fast food are essentially uncontrolled, although individual operations such as charcoal broiling may be using air emission controls. Poultry slaughtering is uncontrolled, whereas rendering is controlled.

Tables 6.2A and 6.2B provide emission factors and the proposed control equipment to achieve them. Significant emission abatement can be and is achieved where such reductions are required, such as in rendering operations. As shown in Table 6.2B, control equipment can result in major reductions of air emissions throughout this sector.

6.2.3 Pulp and Paper and Allied Industries

The most significant reduction of air emissions using improved control technologies in Ontario's Pulp and Paper Industries (2711, 2712 and 2713) would be in particulates. With the use of baghouses and lime injection it would be possible to control acid gases (SO_2) as well as particulates.

NO_x emissions could be reduced using combustion modification-techniques.

The other Ontario industries in this sector involve printing processes and the release of VOCs. Lower VOC emissions are obtained with improved control technologies. The only exception is the wallpaper production industry which is already using a high level of control.

Tables 6.3A and 6.3B provide the emission factors for successive levels of abatement and the control methods to achieve them.

6.2.4 Iron and Steel Industry

The production of ferroalloys (SIC 2911) emits a small amount of air contaminants which can be reduced further by upgrading controls from scrubbers to baghouses.

Steel foundry processes (SIC 2912) are large sources of particulate air emissions. Consequently, they are controlled to a high degree. Some additional improvements can be made through the application of highly efficient air control technologies.

Some processes, such as quenching in coke plants, cannot be readily controlled because of the nature of the source. Fugitive emissions are difficult to contain and represent a potentially large source of emissions.

Particulate emissions from some of the processes, such as the coke plant flue stacks and charging operations, could be reduced by adding scrubbers. Marginal reduction in emissions from other processes may also be attained by upgrading existing controls.

Particulate emissions from other primary steel processes (SIC 2919), especially from electric arc operations, could be reduced by the use of higher efficiency baghouses. The emission factors for this sector are given in Table 6.4A and the technologies to achieve them are provided in Table 6.4B.

6.2.5 Foundry Industries

The Foundries sector controls between half to three quarters of its emissions in Ontario.

The largest source, iron foundries (SIC 2941), controls about 58 percent of all its emissions, with the remainder being vented to the atmosphere. The controlled sources have the highest emission concentrations whereas the vented operations are for diffuse low level emissions having high ventilation rates.

The two other SIC categories (2971 and 2999) have much lower emissions than those produced by iron foundries and thus have lower emission factors.

With more stringent controls, emissions from this sector would decrease substantially.

Tables 6.5A and 6.5B show the unit emission reductions that would be achieved and the equipment that would be required.

6.2.6 Non-Ferrous Smelters and Refineries

Reductions in air emissions are made possible by improving control devices, installing more control devices and using other methods to reduce the amount of contaminants being released into the air. All these approaches are being suggested for the Non-Ferrous Smelters and Refinery Industries (SIC 2959) in Ontario. For example, the existing electrostatic precipitators (ESP) should be upgraded to higher efficiency ESPs to allow fewer air emissions of particulates and metals. In the case of Lead Smelters, improved housekeeping procedures such as the cleaning of roads on the smelters' property would reduce the spread of fugitive lead.

Improved housekeeping and preventive maintenance on control equipment would decrease emissions. For example, routine replacement of filters in baghouses would lessen the chance of leaks and thus reduce the amount of particulates and heavy metals being emitted to the air.

Tables 6.6A and 6.6B provide the emission factors for successive levels of abatement and the equipment and/or procedures proposed to achieve them.

6.2.7 Automotive Industry

The Ontario industries that make up the automotive sector study are all using some form of emission abatement. All the sources, however,are not controlled. Surface coatings (SIC 3231), for example, include a number of operations which release VOCs into large areas that are ventilated to the atmosphere. As a consequence, a significant amount of VOCs, approximately 11.9 kg/car, are released into the ambient air. Some of these emissions could be controlled with more stringent abatement; however, the potential reduction is estimated to be approximately 50 percent.

In the remaining automotive industries which were studied, the most stringent particulate control equipment would be capable of producing five or ten fold reductions in all processes except aluminum wheel production.

Tables 6.7A and 6.7B provide the emission factors for successive levels of abatement and the equipment proposed to achieve them.

6.2.8 Inorganic Chemical Manufacturing Industry

All of the seven industries that make up Ontario's Inorganic Chemical Manufacturing Industry are using air emission control equipment on most of their processes. Most of the emission factors are low indicating good control or low emission rates.

Further abatement could be achieved by applying stringent controls; the improvements, however, would not produce large reductions in emissions for most contaminants.

Some contaminant concentrations are currently being controlled to the lowest levels achievable.

Tables 6.8A and 6.8B provide the emission factors for successive levels of abatement and the equipment proposed to achieve them.

6.2.9 Petroleum Refining Industry

The Petroleum Refining Industries (SIC 3611) in Ontario use air emission control equipment, a continuous program of maintenance and clean fuels to reduce their emissions. More stringent controls and greater use of clean fuels could reduce the amounts of contaminants emitted into the atmosphere.

Low NO_x burners are used to reduce NO_x but other combustion modifications may be capable of obtaining further reductions.

Use of lower sulphur fuels in process combustion boilers and catalytic cracking would reduce SO_2 emissions.

Increased boiler efficiency would increase HC and CO destruction and the use of enclosed pneumatic processes would curtail fugitive releases of volatiles.

Tables 6.9A and 6.9B provide emission factors for successive levels of abatement and the required equipment or control alternatives to achieve them.

6.2.10 Asphalt Paving Industry

The air emissions generated by the Asphalt Paving Industry (SIC 3699) can be reduced by replacing the venturi scrubbers currently used by some portable asphalt plants with new scrubbers and by improving the quality of some of the baghouses now used by permanent and portable plants.

The existing degree of abatement is high and the implementation of the most stringent control scenario would reduce the particulate emissions by approximately 50 percent.

Tables 6.10A and 6.10B provide the emission factors for successive levels of abatement and the controls to achieve them.

6.2.11 The Petrochemical Products Industry

The Petrochemical sector emissions are controlled to abate VOCs, NO_X and particulate matter, including heavy metals.

Some industries, such as paint and varnish (SIC 3751), plastics and synthetic resins (SIC 3731), printing ink (SIC 3791), and solvent reclamation (3799), do not usually control VOC emissions escaping from their processes. Consequently, their existing unit emissions are relatively large.

If controls were placed on all processes in this sector emitting VOCs, up to a 10-fold decrease could be achieved.

Particulates are also reduced with more controls but only with the most stringent abatement measures is a five to seven-fold decrease achieved.

Tables 6.11A and 6.11B provide the emission factors for successive levels of abatement and the proposed equipment to achieve those reductions.

6.2.12 Electric Power Generation

The existing emissions of particulates per million megawatt hours at all the electrical generating stations (SIC 4911) are lower than would be allowed under Level 3 abatement.

All of the stations presently use electrostatic precipitators to control particulates and these would be upgraded or used in combination with baghouses to achieve Level 2 abatement.

With baghouse controls on all bituminous and lignite fired units, Level 1 abatement would be achieved. The oil fired plant meets Level 1 abatement now.

Tables 6.12A and 6.12B provide the emission factors and control equipment needed for the various levels of abatement.

6.2.13 Waste Disposal Industry

Incineration, landfill and recycling represent the methods currently being used to dispose of solid waste (SIC 4999). Recycling is a recent initiative and is projected to reduce the municipal solid wastes (MSW) by about 15 percent when fully implemented. The remaining 85 percent (MSW) plus an equivalent or greater amount of waste from commercial and industrial sources is incinerated or disposed of directly in landfills. Sewage sludge is also disposed of in landfills or incinerated.

Hospital wastes include pathological wastes as well as plastics and other materials. In order to treat the pathological wastes adequately, hospital wastes either have to be segregated then rendered harmless or they have to be incinerated in specially designed pathological incinerators.

The emission factors for successive levels of abatement and the control equipment to achieve those levels are described in Tables 6.13A and 6.13B.

References - Chapter 6

Dunbar, D. and Rust, G., 1985. *BACT/LAER (Best Available Control Technology/Lowest Achievable Emission Rate).* Clearinghouse: A Compilation of Control Technology Determinations: Volume II- C, Appendix G - Source Type Codes 8-12. EPA Report No. EPA-450/3-85-016D.

South Coast Air Quality Management District, 1983. *Best Available Control Technology.* Revised February 1988.

U.S. EPA 1985. *Compilation of Air Pollutant Emission Factors Vol. 1. Stationary Point and Area Sources.* AP-42 Fourth Edition, Vol. 1., September. Supplements.

TABLE 6.1A

OPEN PIT MINING
EMISSION RATES REQUIRED TO SATISFY
ALTERNATIVE ABATEMENT LEVELS

(kg/tonne)

			Abatement Level		
	Mine Type	Emission	Existing	3	2 & 1
0611	Gold	PM	2.1	1.7	1.4
0617	Iron	PM	2.6	2.1	1.8

TABLE 6.1B

OPEN PIT MINING
CONTROL SYSTEMS REQUIRED TO SATISFY
ALTERNATIVE ABATEMENT LEVELS

		Abatement Level		
	Mine Type	Existing	3	2 & 1
0611	Gold	Watering as required	Frequent and Regular Watering of Roads	Chemical Dust Suppression
0617	Iron			

TABLE 6.2A

FOOD INDUSTRY
EMISSION RATES REQUIRED TO SATISFY
ALTERNATIVE ABATEMENT LEVELS
(kg/tonne)

SIC Code & Manufacturing Processes	Emission	Abatement Level			
		Existing	3	2	1
1011 - Meat & Meat Products(1) Slaughter Houses Rendering Processing	- Particulates (kg/tonne)	.15	.15	.03	.01
	- VOCs (kg/tonne)	.18	.18	.06	.02
	- Odour (per facility)	14.3×10^9	14.3×10^9	9.3×10^6	4.7×10^6
1012 - Poultry & Poultry Products Slaughter Houses Rendering Processing	- Particulates (kg/tonne)	.15	.15	.03	.01
	- VOCs (kg/tonne)	.18	.18	.06	.02
	- Odour	1.7×10^9	1.7×10^9	9.3×10^6	4.7×10^6
1021 - Fish Products Processing	- Particulates (kg/tonne)	.44	.44	.03	.01
	- VOCs (kg/tonne)	.44	.44	.06	.02
1049 - Other Dairy Cheese Skim Milk Powder Evaporated Milk	- Particulates (kg/tonne)	.14	.14	.001	.0005
9211, 9212, 9213 Restaurants		5.8×10^9	5.8×10^9	5.8×10^6	5.8×10^6

Notes:

(1) Most of the emissions come out of rendering and processing. Therefore, particulates, VOCs and odour apply to this type of plant.

TABLE 6.2B

FOOD INDUSTRY
CONTROL SYSTEMS REQUIRED TO SATISFY ALTERNATIVE ABATEMENT LEVELS

SIC Code & Manufacturing Processes	Existing	Abatement Level 3	2	1
1011 - Meat & Meat Products				
Slaughter Houses	Scrubber	Scrubber	Incinerator	Incinerator
Rendering	Scrubber	Scrubber	Incinerator	Incinerator
Processing	Baghouse	Baghouse	Baghouse	Incinerator
1012 - Poultry & Poultry Products				
Slaughter Houses	UC	UC	Scrubber	Incinerator
Rendering	Scrubber	Scrubber	Scrubber	Incinerator
Processing	Baghouse	Baghouse	Baghouse	Incinerator
1021 - Fish Products				
Processing	UC	UC	Scrubber	Incinerator
1049 - Other Dairy				
Cheese	Scrubber	Scrubber	Scrubber & Baghouse	Scrubber & Baghouse
Skim Milk Powder	Baghouse	Baghouse	Baghouse	Baghouse
Evaporated Milk	Mist Elim.	Mist Elim.	Mist Elim.	Mist Elim.
9211, 9212, 9213 Restaurants	UC	UC	Ecology Unit	Ecology Unit

TABLE 6.3A

PULP AND PAPER AND ALLIED INDUSTRIES
EMISSION RATES TO SATISFY
ALTERNATIVE ABATEMENT LEVELS

(kg/tonne of production)

SIC Code & Manufacturing Processes	Abatement Level	Emission						
		PM	SO_2	NO_x	CO	Cl_2	ClO_2	VOCs
2711 Kraft Pulp Mills								
Recovery Boilers	Existing	5.4	3.41	0.79	1.15	0	0	
	3	1	3.41	0.79	1.15	0	0	
	2	0.54	1.7	0.79	1.15	0	0	
	1	0.25	1.7	0.79	1.15	0	0	
Lime Kiln	Existing	1.62	0.09	0.62	3.84	0	0	
	3	0.81	0.09	0.62	3.84	0	0	
	2	0.81	0.09	0.25	3.84	0	0	
	1	0.61	0.09	0.25	3.84	0	0	
Smelt Dissolving Tank	Existing	0.18	0.03	0	0	0	0	
	3	0.09	0.03	0	0	0	0	
	2	0.09	0.03	0	0	0	0	
	1	0.09	0.03	0	0	0	0	
Bleach Plant	Existing	0	0	0	0	0.6	0.02	
	3	0	0	0	0	0.6	0.02	
	2	0	0	0	0	0.6	0.02	
	1	0	0	0	0	0.3	0.01	
Steam Boilers	Existing	.09	6.8	1.62	1.74	neg.	neg.	
	3	.09	6.8	1.62	1.74	neg.	neg.	
	2	.03	0.5	0.4	1.74	neg.	neg.	
	1	.03	0.5	0.4	1.74	neg.	neg.	

TABLE 6.3A (Continued)

SIC Code & Manufacturing Processes	Abatement Level	Emission						
		PM	SO_2	NO_x	CO	Cl_2	ClO_2	VOCs
2712 - Newsprint Mills w/Kraft Pulp								
. Recovery Boiler	Existing	3.05	2.2	.45	.62	neg.	neg.	
	3	.55	2.2	.45	.62	neg.	neg.	
	2	.31	1.1	.45	.62	neg.	neg.	
	1	.05	1.1	.45	.62	neg.	neg	
. Lime Kiln	Existing	.92	.05	.35	2.06	neg.	neg.	
	3	.46	.05	.35	2.06	neg.	neg.	
	2	.46	.05	.35	2.06	neg.	neg.	
	1	.09	.05	.35	2.06	neg.	neg.	
. Smelt Dissolving Tanks	Existing	.10	.03	neg.	neg.	neg.	neg.	
	3	.05	.03	neg.	neg.	neg.	neg.	
	2	.05	.03	neg.	neg.	neg.	neg.	
	1	.05	.03	neg.	neg.	neg.	neg.	
. Bleach Plant	Existing	neg.	neg.	neg.	neg.	.15	.2	
	3	neg.	neg.	neg.	neg.	.15	.2	
	2	neg.	neg.	neg.	neg.	.15	.2	
	1	neg.	neg.	neg.	neg.	.07	.1	
. Steam Boilers	Existing	.09	1.4	1.1	1.6	neg.	neg.	
	3	.04	1.4	1.1	1.6	neg.	neg.	
	2	.03	.5	0.4	1.6	neg.	neg.	
	1	.03	.5	0.4	1.6	neg.	neg.	

TABLE 6.3A (Continued)

SIC Code & Manufacturing Processes	Abatement Level	Emission						
		PM	SO_2	NO_x	CO	Cl_2	ClO_2	VOCs
- Newsprint Mills w/Sulphite Pulping								
. Blowpit Stack	Existing	0	0.5	neg.	neg.	neg.	neg.	
	3	0	0.5	neg.	neg.	neg.	neg.	
	2	0	0.3	neg.	neg.	neg.	neg.	
	1	0	0.1	neg.	neg.	neg.	neg.	
. Acid Plant	Existing	0	0.2	neg.	neg.	neg.	neg.	
	3	0	0.2	neg.	neg.	neg.	neg.	
	2	0	0.1	neg.	neg.	neg.	neg.	
	1	0	0.1	neg.	neg.	neg.	neg.	
. Steam Boilers	Existing	0.5	0.7	0.5	1.2	neg.	neg.	
	3	0.04	0.7	0.5	1.2	neg.	neg.	
	2	0.03	0.7	0.4	1.2	neg.	neg.	
	1	0.03	0.5	0.4	1.2	neg.	neg.	
- Newsprint Mills w/Groundwood Pulping								
. Steam Boilers	Existing	1.50	5.0	0.8	3.1	neg.	neg.	
	3	0.04	5.0	0.8	3.1	neg.	neg.	
	2	0.03	0.5	0.4	3.1	neg.	neg.	
	1	0.03	0.5	0.4	3.1	neg.	neg.	
- Newsprint Mills								
. Steam Boilers	Existing	0.94	4.7	0.9	1.4	neg.	neg.	
	3	0.04	4.7	0.9	1.4	neg.	neg.	
	2	0.03	0.5	0.4	1.4	neg.	neg.	
	1	0.03	0.5	0.4	1.4	neg.	neg.	

TABLE 6.3A (Continued)

SIC Code & Manufacturing Processes	Abatement Level	Emission						
		PM	SO_2	NO_x	CO	Cl_2	ClO_2	VOCs
2713 - Paperboard Mills w/Kraft Pulping								
. Recovery Boiler	Existing	11.47	3.82	1.45	2.29	neg.	neg.	
	3	11.47	3.82	1.45	2.29	neg.	neg.	
	2	5.74	1.91	1.45	2.29	neg.	neg.	
	1	5.74	1.91	1.45	2.29	neg.	neg.	
. Lime Kiln	Existing	3.44	.11	1.14	7.65	neg.	neg.	
	3	1.72	.11	1.14	7.65	neg.	neg.	
	2	1.72	.11	1.14	7.65	neg.	neg.	
	1	.34	.11	1.14	7.65	neg.	neg.	
. Smelt Dissolving Tank	Existing	.19	.04	neg.	neg.	neg.	neg.	
	3	.10	.04	neg.	neg.	neg.	neg.	
	2	.10	.04	neg.	neg.	neg.	neg.	
	1	.10	.04	neg.	neg.	neg.	neg.	
. Bleach Plant	Existing	neg.	neg.	neg.	neg.	.25	.1	
	3	neg.	neg.	neg.	neg.	.25	.1	
	2	neg.	neg.	neg.	neg.	.25	.1	
	1	neg.	neg.	neg.	neg.	.13	.1	
. Steam Boilers	Existing	0.94	0.28	0.78	1.53	neg.	neg.	
	3	0.04	0.28	0.78	1.53	neg.	neg.	
	2	.03	0.28	0.4	1.53	neg.	neg.	
	1	.03	0.28	0.4	1.53	neg.	neg.	

TABLE 6.3A (Continued)

SIC Code & Manufacturing Processes	Abatement Level	Emission						
		PM	SO_2	NO_x	CO	Cl_2	ClO_2	VOCs
- Paperboard Mills w/ Semi-Chemical Pulping								
. Steam Boilers	Existing	0.94	0.27	0.86	0.22	neg.	neg.	
	3	0.04	0.27	0.86	0.22	neg.	neg.	
	2	0.03	0.27	0.4	0.22	neg.	neg.	
	1	0.03	0.27	0.4	0.22	neg.	neg.	
- Paperboard Mills								
. Steam Boiler	Existing	0.45	0.01	0.14	0.04	neg.	neg.	
	3	0.04	0.01	0.14	0.04	neg.	neg.	
	2	0.03	0.01	0.14	0.04	neg.	neg.	
	1	0.03	0.01	0.14	0.04	neg.	neg.	
2811 - Business Forms Industry	Existing							400
	3							400
	2							4
	1							4
2819 - Other Commercial Printing Industry	Existing							750
	3							750
	2							75
	1							7.5
2821 - Plate Making, Type Setting and Binding Industry	Existing							114
	3							16
	2							13.4
	1							3.4

TABLE 6.3A (Continued)

SIC Code & Manufacturing Processes	Abatement Level	Emission						
		PM	SO_2	NO_x	CO	Cl_2	ClO_2	VOCs
2841 - Magazines and Newspaper Industry	Existing							394
	3							95
	2							7.5
	1							0.75
2849 - Other Combined Publishing Printing Industry								
. Wallpaper	Existing							0.07
	3							0.07
	2							0.07
	1							0.07
. Other	Existing							600
	3							600
	2							30
	1							6

TABLE 6.3B

PULP AND PAPER AND ALLIED INDUSTRIES CONTROL SYSTEMS TO SATISFY ALTERNATIVE ABATEMENT LEVELS

SIC Code & Manufacturing Processes	Abatement Level			
	Existing	3	2	1
2711 - Kraft Pulp Mills				
. Recovery Boiler	ESP	HE ESP	Baghouse & Lime	HE Baghouse & Lime
. Lime Kiln	Scrubber	ME Scrubber	HE Scrubber & Low Nox Burner	HE Scrubber & Low Nox Burner
. Smelt Tank	Scrubber	ME Scrubber	HE Scrubber	HE Scrubber
. Bleach Plant	Scrubber	Scrubber	Scrubber	HE Scrubber
. Boilers	Multiclone	Baghouse	Baghouse, Lime Low Nox Burner	Baghouse, Lime Low Nox Burner
2712 - Newsprint Mills w/Kraft Pulp				
. Recovery Boiler	ESP	HE ESP	Baghouse & Lime	HE Baghouse & Lime Cartridge
. Lime Kiln	Scrubber	ME Scrubber	HE Scrubber	HE Scrubber
. Smelt Tanks	Scrubber	ME Scrubber	HE Scrubber	HE Scrubber
. Bleach Plant	Scrubber	ME Scrubber	HE Scrubber	HE Scrubber

TABLE 6.3B (Continued)

SIC Code & Manufacturing Processes	Abatement Level			
	Existing	3	2	1
. Boilers	Multiclones	Baghouse	Baghouse & Lime Low Nox Burner	HE Baghouse & Lime Lox Nox Burner
- Newsprint Mills w/Sulphite Pulping				
. Blowpit Stack	Scrubber	Scrubber	HE Scrubber	HE Scrubber
. Acid Plant	Caustic Scrubber	Caustic Scrubber	He Caustic Scrubber	HE Caustic Scrubber
. Steam Boilers	Multiclones	Baghouse	Baghouse & Low Nox Burner	HE Baghouse & Low Nox Burner & Lime Cartridges
- Newsprint Mills w/Groundwood Pulping				
. Steam Boilers	UC	Baghouse	Baghouse & Lime Low Nox Burner	HE Baghouse & Lime Low Nox Burner
- Newsprint Mills				
. Steam Boilers	UC	Baghouse	Baghouse & Lime Low Nox Burners	HE Baghouses & Lime Low Nox Burners
2713 - Paperboard Mills w/Kraft Pulping				
. Recovery Boiler	ESP	HE ESP	Baghouse	HE Baghouse & Lime Cartridges
. Lime Kiln	Scrubber	ME Scrubber	HE Scrubber & Low NO_x Burner	HE Scrubber & Low NO_x Burner

TABLE 6.3B (Continued)

SIC Code & Manufacturing Processes	Abatement Level			
	Existing	3	2	1
. Smelt Tank	Scrubber	ME Scrubber	ME Scrubber	HE Scrubber
. Bleach Plant	ME Scrubber	ME Scrubber	ME Scrubber	HE Scrubber
. Boilers	UC	Baghouse	Baghouse & Low Nox Burner	Baghouse Low Nox Burner
- Paperboard Mills w/ Semi-Chemical Pulping				
. Steam Boilers	UC	Baghouse	Baghouse & Low Nox Burner	HE Baghouse & Low Nox Burner
- Paperboard Mills				
. Steam Boilers	UC	Baghouse	Baghouse	Baghouse
2811 - Business Forms Industry	UC	UC	Afterburner	Afterburner & Carbon Absorber
2819 - Other Commercial Printing Industry	UC	UC	Carbon Absorber	Afterburner

TABLE 6.3B (Continued)

SIC Code & Manufacturing Processes	Abatement Level			
	Existing	3	2	1
2821 - Plate Making, Type Setting and Binding Industry	UC & Catalytic Incineration	Catalytic Incineration	HE Catalytic Incineration	Thermal Incineration
2841 - Magazines and Newspaper Industry	UC & Catalytic Incineration	Catalytic Incineration	HE Catalytic Incineration	Thermal Incineration
2849 - Other Combined Publishing Printing Industry	UC & Catalytic Incineration	Catalytic Incineration	HE Catalytic Incineration	Thermal Incineration

TABLE 6.4A

IRON AND STEEL INDUSTRY
EMISSION RATES REQUIRED TO SATISFY
ALTERNATIVE ABATEMENT LEVELS

(kg/1000 tonne of production)

SIC Code & Manufacturing Processes	Emission	Abatement Level Existing	3	2	1
2911 Ferroalloy					
. Exothermic	Particulate	14.0	14.0	.224	.224
2912 Steel Foundries					
. Coke Plants	Particulates				
- Charging		49.2	49.2	25.7	1.3
- Pushing		9.7	9.7	9.7	9.7
- Quenching		60.3	60.3	60.3	60.3
- Flue Stacks		97.3	97.3	20.2	10.1
. Blast & Open Hearth Furnace					
- Melting		43.1	43.1	43.1	43.1
- Heating		5.0	5.0	5.0	5.0
- Dekishing		4.2	4.2	4.2	4.2
- Desulphuring		12.1	12.1	4.2	.6
- Fugitive Emissions		84.3	84.3	30.1	14.6
. Basic Oxygen Furnace					
- Charging		84.2	84.2	84.2	42.1
- Tapping		2.4	2.4	2.4	2.4
- Transfer		2.1	2.1	2.1	2.1
- Melting & Refining		24.9	24.9	24.9	24.9
- Fugitive Emissions		216.7	216.7	216.7	108.3
2919 Other Primary Steel					
. Electric Arc	Particulates	155	155	142	71
. Boilers Scarfing & Pits	Particulates	20	15	15	5.0

TABLE 6.4B

IRON AND STEEL INDUSTRY CONTROL SYSTEMS REQUIRED TO SATISFY ALTERNATIVE ABATEMENT LEVELS

SIC Code & Manufacturing Processes	Abatement Level			
	Existing	3	2	1
2911 Ferroalloy				
. Exothermic	Scrubber	Scrubber	Baghouse	Baghouse
2912 Steel Foundries				
. Coke Plants				
jing	UC	UC	Scrubber	Baghouse
shing	ESP/Baghouse/ Scrubber	Scrubber	HE Scrubber	Baghouse
- Quenching	UC	UC	UC	UC
- Flue Stacks	UC	UC	Scrubber	HE Scrubber
. Blast & Open Hearth Furnace				
- Melting	Baghouse/Scrubber	Baghouse/Scrubber	Baghouse/Scrubber	Baghouse/Scrubber
- Heating	UC	UC	UC	UC
- Dekishing	Scrubber	Scrubber	Scrubber	Scrubber
- Desulphuring	Scrubber	Scrubber	HE Scrubber	Venturi Scrubber
- Fugitive Emissions	UC	Scrubber	ESP	Baghouse
. Basic Oxygen Furnace				
- Charging	Baghouse/Scrubber	Baghouse/Scrubber	Baghouse/Scrubber	HE Baghouse
- Tapping	Baghouse	Baghouse	Baghouse	Baghouse
- Transfer	Baghouse	Baghouse	Baghouse	Baghouse
- Melting & Refining	Baghouse	Baghouse	Baghouse	Baghouse
- Fugitive Emissions	UC	Scrubber	ESP	Baghouse
2919 Other Primary Steel				
. Electric Arc	Baghouse	Baghouse	HE Baghouse	HE Baghouse & LOW NO_x Burner
. Boilers Scarfing & Pits	UC	Baghouse	HE Baghouse	HE Baghouse, Lime Scrubber & Low NO_x Burners

TABLE 6.5A

FOUNDRIES
EMISSION RATES REQUIRED TO SATISFY ALTERNATIVE ABATEMENT LEVELS

(kg/tonne of production)

SIC Code & Manufacturing Process	Emission	Abatement Level			
		Existing	3	2	1
2941 Iron Foundries	Particulate	7.2	3.6	1.6	0.8
2971 Copper and Brass Works	Particulate	3.9	1.4	1.4	.7
2999 Rolled Casting					
. Copper	Particulate	6.8	1.8	1.8	1.0
. Aluminum	Particulate	3.0	1.8	0.9	0.04
	VOCs	0.04	0.04	0.04	0.04

TABLE 6.5B

FOUNDRIES
CONTROL SYSTEMS REQUIRED TO SATISFY ALTERNATIVE ABATEMENT LEVELS

SIC Code & Manufacturing Process	Abatement Level			
	Existing	3	2	1
2941 Iron Foundries	Afterburner & 58% with baghouses	Afterburner & baghouse	Afterburner & HE baghouse	Afterburner & HE baghouse
2971 Copper and Brass Works	25% UC, remainder Baghouse	HE Baghouse	HE Baghouse	HE Baghouse Exhaust Filters & Enclosures
2999 Rolled Casting				
. Copper	50% UC 50% Scrubber	Scrubber	Baghouse	HE Baghouse
. Aluminum	50% UC 50% Scrubber	Scrubber	Baghouse	HE Baghouse

TABLE 6.6A

NON-FERROUS SMELTERS AND REFINERIES EMISSION RATES TO SATISFY ALTERNATIVE ABATEMENT LEVELS

(kg/tonne of production)

Plant Type	SIC Code	Emission	Abatement Level Existing	3	2	1
Primary Non-Ferrous Industry	2959	Particulate	20.9	13.9	2.79	1.39
		Arsenic	.18	.13	.02	.012
		Copper	.96	.64	.13	.064
		Iron	2.57	1.71	.34	1.72
		Lead	.29	.19	.04	.019
		Nickel	.67	.45	.09	.047
		Zinc	.04	.03	.01	.003
Secondary Lead Smelters		Particulate	.66	.66	.66	.66
		Lead	.06	.06	.06	.06

TABLE 6.6B

NON-FERROUS SMELTERS & REFINERIES
CONTROL SYSTEMS TO SATISFY
ALTERNATIVE ABATEMENT LEVELS

	Abatement Level			
Source	Existing	3	2	1
Primary Smelter	Baghouses	Baghouses	Baghouses	Baghouses
	Cyclones	Cyclones	Cyclones	Cyclones
	ESPs - Dry	HE ESPS - Dry		
	ESPs - Wet	HE ESPs - Wet	HE ESPs - Wet	HE ESPs - Wet
	Scrubbers	Scrubbers	Scrubbers	Scrubbers
Secondary Lead Smelter	Baghouses	Baghouses	Baghouses	Baghouses
	Wet Scrubber	Wet Scrubber	Wet Scrubber	Wet Scrubber
	Mist Eliminator	Mist Eliminator	Mist Eliminator	Mist Eliminator
			Housekeeping	Housekeeping
			Preventive Maintenance	Preventive Maintenance

Table 6.7A

AUTOMOTIVE INDUSTRY
EMISSION RATES TO SATISFY
ALTERNATIVE ABATEMENT LEVELS

SIC Code and Manufacturing Processes	Emission	Abatement Level			
		Existing	3	2	1
3231 - automobile and light duty truck surface coating	VOC	11.9 kg/ car	8.3 kg/ car	5.8 kg/ car	5.4 kg/ car
3254 -steering and suspension	Other Particulates	420 kg/ 1000 tonnes of production	420 kg/ 1000 tonnes of production	420 kg/ 1000 tonnes of production	42 kg/ 1000 tonnes of production
3255 - brake lining production	Other Particulates	87.5 kg/ 1000 tonnes of production	87.5 kg/ 1000 tonnes of production	87.5 kg 1000 tonnes of production	17.5 kg/ 1000 tonnes of production
	Asbestos	37.5 kg/ 1000 tonnes of production	37.5 kg/ 1000 tonnes of production	37.5 kg/ 1000 tonnes of production	7.5 kg/ 1000 tonnes of production
aluminum wheel production	Talc	19 kg/ 1000 wheels	19 kg/ 1000 wheels	19 kg/ 1000 wheels	19 kg/ 1000 wheels
3259 - wet cell automotive battery production	Lead	6.94 kg/ 1000 batteries	3.82 kg/ 1000 batteries	.7 kg/ 1000 batteries	.35 kg/ 1000 batteries

Table 6.7B

AUTOMOTIVE INDUSTRY
CONTROL SYSTEMS REQUIRED TO SATISFY
ALTERNATIVE ABATEMENT LEVELS

SIC Code and Manufacturing Processes	Abatement Level			
	Existing	3	2	1
3231 - automobile and light duty truck surface coating	dispersion	catalytic incinerator	high efficiency catalytic incinerator	thermal incinerator
3254 - steering and suspension	baghouse	baghouse	baghouse	high efficiency baghouse
3255 - brake lining production	baghouse	baghouse	baghouse	high efficiency baghouse
- aluminum wheel production	baghouse	baghouse	baghouse	baghouse
3259 - wet cell automotive battery production	high velocity low efficiency baghouse plus scrubber	low velocity low efficiency baghouse plus scrubber	low velocity medium efficiency baghouse	low velocity high efficiency baghouse

TABLE 6.8A

INORGANIC CHEMICAL MANUFACTURING INDUSTRY EMISSION RATES TO SATISFY ALTERNATIVE ABATEMENT LEVELS

(kg/tonne)

SIC Code & Manufacturing Processes	Emission	Abatement Level			
		Existing	3	2	1
3511 - Domestic Clay	VOC	neg.	neg.	neg.	neg.
. Tunnel Kiln	SO_2	.44	.44	.22	.22
	NO_x	.07	.07	.07	.04.
	HF	0.4	0.4	0.1	.009
	Particulate	.07	.07	.03	.007
. Gas Fired Dryer	Particulate	.006	.006	.006	.006
	SO_2	.55	.55	.28	.28
. Raw materials	Particulate	.17	.17	.085	.01
3512 - Imported Clay	Particulate				
	Baghouse	.35	.35	.35	.07
	Water wash house	11.4	11.4	11.4	2.28
3521 - Cement					
. Wet Kiln	Particulate	0.16	0.16	0.11	0.055
	SO_2	29.6	29.6	15.0	15.0
	NO_x	3.24	3.24	3.24	3.24
. Dry Kiln	Particulate	0.19	0.19	0.13	0.065
	SO_2	29.6	29.6	15.0	15.0
	NO_x	3.24	3.24	3.24	3.24
. Clinker Cooler					
Fabric Filter	Particulate	0.516	0.516	0.026	0.026
Gravel Bed Filter		0.516	0.516	0.026	0.026
. Raw Feed Mills and Handling	Particulate	0.045	0.045	0.023	0.023
. Finish Mills	Particulate	0.065	0.065	0.033	0.033
. Materials Handling and Storage	Particulate	0.036	0.036	0.018	0.018
3571 - Abrasives Industry					
. Aluminum Oxide	Particulate	1.64	0.82	0.42	0.42
. Silicon Carbide	SO_2	16.0	1.6	1.6	0.81
	H_2S	0.058	neg.	neg.	neg.
	Particulate	1.64	0.82	0.42	0.42
3581 - Lime Industry					
. Lime Calcining	Particulate	0.538	0.538	0.538	0.269
. Hydration	Particulate	0.05	0.05	0.05	0.03
. Crushing and Grinding	Particulate	0.486	0.146	0.146	0.007
. Stockpiles	Particulate	0.0034	0.0034	0.0017	0.0017
. Storage	Particulate	0.0031	0.0031	0.0016	0.0016

TABLE 6.8A (Continued)

SIC Code & Manufacturing Processes	Emission	Abatement Level			
		Existing	3	2	1
3711 - General Inorganic Chemicals Industry					
. Ammonium Products	Particulate	0.734	0.247	0.073	0.036
	NO_x	0.146	0.146	0.088	0.052
	HC	1.311	0.656	0.131	0.013
	NH_3	0.292	0.292	0.058	0.029
	F	0.0036	0.0036	0.0032	0.00003
	SO_2	0.907	0.907	0.055	0.03
. Ammonium Phosphate	Particulate	0.141	0.141	0.007	0.001
	HC	0.0076	0.0076	0.0076	0.0076
. Urea and Carbon	Particulate	1.4	1.4	0.42	0.14
	NO_x	0.1	0.1	0.08	0.05
	HC	1.3	1.3	0.13	0.013
	NH_3	0.00002	0.000006	0.000002	0.00000
	SO_2	0.21	0.2	0.08	0.02
. Phosphoric Acid	Particulate	0.531	0.531	0.531	0.053
	HC	0.139	0.139	0.139	0.014
	F	0.012	0.012	0.012	0.001
. Carbon Pellets	Particulate	4.0	4.0	0.4	0.4
	VOC	23.0	23.0	23.0	0.23
. Nitric Acid	Particulate	0.128	0.128	0.128	0.128
	NO_x	1.68	1.68	1.01	0.59
	HC	0.007	0.007	0.007	0.0007
	NH_3	0.071	0.071	0.071	0.071
. Ammonium Nitrate Wet Scrubber (63%)	Particulate	0.056	0.056	0.056	0.006
	HC	0.021	0.021	0.021	0.002
	NH_3	0.193	0.193	0.193	0.019
	N. Acid	0.028	0.028	0.028	0.003
. Ammonium Nitrate Wet Scrubber (99.5%)	Particulate	0.057	0.057	0.057	0.006
	HC	0.009	0.009	0.009	0.002
	NH_3	0.183	0.183	0.183	0.018
	N. Acid	0.025	0.025	0.025	0.003
. Ammonium Phosphate	Particulate	0.15	0.15	0.003	0.0025
	HC	2.7	2.7	2.7	2.7
	NH_3	0.069	0.069	0.069	0.069
	F	0.040	0.011	0.005	0.001
3721 - Fertilizer Industry	Particulate	0.011	0.011	0.005	0.001

TABLE 6.8B

INORGANIC CHEMICAL MANUFACTURING INDUSTRY CONTROL SYSTEMS TO SATISFY ALTERNATIVE ABATEMENT LEVELS

SIC Code & Manufacturing Processes		Abatement Level		
	Existing	3	2	1
3511 - Domestic Clay				
. Raw Material Handling	Baghouse	Baghouse	Baghouse & Wet/Dry Collector	Baghouse & Wet/Dry Collector
. Tunnel Kiln	Baghouse	Baghouse	Lime Scrubber, Low Sulphur Fuel	Lime Scrubber, Low Sulphur Fuel
. Dryer	UC	UC	Baghouse & Wet/Dry Collector	Baghouse & Wet/Dry Collector
3512 - Imported Clay	Baghouse & Wash Booth	Baghouse & Wash Booth	Baghouse, Wash Booth & Scrubber	Baghouse, Wash Booth & Scrubber
3521 - Cement				
. Wet Kiln	ESP	ESP	ME ESP	ESP, Baghouse & Catalytic Reduction
. Dry Kiln	ESP	ESP	ME ESP	ESP, Baghouse & Catalytic Reduction
. Clinker Cooler	Baghouse/Gravel Bed Filter	Baghouse	Baghouse	HE Baghouse
. Other Processes	Baghouse	Baghouse	HE Baghouse	HE Baghouse
3571 - Abrasives				
. Aluminum Oxide	Baghouse	HE Baghouse	HE Baghouse & Filter	HE Baghouse & Filter
. Silicon Carbide	Baghouse, Incinerator & High Stack	HE Baghouse, Incinerator & High Stack	HE Baghouse Scrubbers	HE Baghouse Scrubbers
3581 - Lime				
. Calcining	ESP	ESP	HE ESP	HE ESP
. Cooling	UC	Vent to Kiln	Vent to Kiln	Vent to Kiln
. Hydration	Water Spray Tower	Water Spray Towers	Scrubber	HE Scrubber

TABLE 6.8B (Continued)

SIC Code & Manufacturing Processes	Abatement Level			
	Existing	3	2	1
. Crushing	UC	Cyclone & Baghouse	Cyclone & Baghouse	Cyclone & Baghouse
. Stockpiles	Water Sprays	Water Sprays	Water Sprays & Screening	Water Sprays & Screening
. Storage	Baghouse	Baghouse	Baghouse	Baghouse
3711 - General Inorganic Chemicals				
. Ammonia Products	UC	Cyclone, Scrubber	Scrubber, Thermal DeNox & Incinerator	ESP, Scrubber, After Burner, SCR
. Ammonia Phosphate	Cyclone	Cyclone	ESP	Baghouse
. Urea Carbon Products	Baghouse	Baghouse & Spray Tower	Baghouse,Thermal DeNox, Afterburner & Scrubber	HE Baghouse, SCR HE Afterburner HE Scrubber
. Phosphoric Acid	Packed Tower	Packed Tower	Packed Tower	Scrubber
. Carbon Pellets	Thermal Incinerator	Thermal Incinerator	Baghouse	HE Baghouse
. Nitric Acid	Catalytic Reduction	Catalytic Reduction	Catalytic Reduction & Thermal DeNox	Catalytic Reduction & SCR
. Ammonium Nitrate	Scrubber	Scrubber	HE Scrubber	HE Scrubber Carbon Absorption
. Ammonium Nitrate	Scrubber	Scrubber	Scrubber	Scrubber Afterburner
. Ammonium Phosphate	Scrubber	Scrubber	ME Baghouse	HE Baghouse
3721 Fertilizer Mixing	Cyclone & Baghouse	Cyclone & Baghouse	Cyclone & Baghouse	Cyclone & HE Baghouse

TABLE 6.9A

PETROLEUM REFINING
EMISSION RATES REQUIRED TO SATISFY ALTERNATIVE ABATEMENT LEVELS
(SIC 3611)

(kg/tonne of production)

	Abatement Level	Emission			
		SO_2	NO_x	PM	Hydrocarbon (VOC)
Process Combustion	Existing	0.429	0.22	0.0975	0.0032
	3	0.425	0.132	0.0486	0.0016
	2	0.227	0.132	0.0243	0.0010
	1	0.110	0.100	0.0120	0.0010
Boilers		0.505			
		0.505			
		0.263			
		0.11			
Catalytic Cracking	Existing	0.293	0.0487	0.0600	
	3	0.280	0.0322	0.0400	
	2	0.140	0.0322	0.0250	
	1	0.140	0.025	0.0250	
Sulphur Plant Tail Gas		0.188			
		0.188			
		0.094			
		0.070			
Storage Tanks	Existing			0.0659	
	3			0.0659	
	2			0.0500	
	1			0.0500	
Pumps and Compressors	Existing			0.023	
	3			0.018	
	2			0.018	
	1			0.010	

TABLE 6.9B

PETROLEUM REFINING CONTROL SYSTEMS REQUIRED TO SATISFY ALTERNATIVE ABATEMENT LEVELS (SIC 3611)

	Abatement Level			
Processes	Existing	3	2	1
Process Combustion and Boilers	Oil Fired	Fuel Switching and Combustion Modification	Fuel Switching and Combustion Modification	Fuel Switching and Combustion Modification SCR HE Cyclone and Baghouse
Catalytic Cracking	Cyclone	Cyclone & ESP	HE Cyclone & ESP	Flue Gas Treatment
Sulphur Plant	UC	UC	Tail Gas Scrubber	Tail Gas Scrubber
Storage Tanker	Floating & Fixed Roof	Floating & Fixed Roof	Floating Roof	Floating Roof
Pumps & Compressors	Existing Maintenance	Existing Maintenance	Heightened Maintenance	Extremely Heightened Maintenance

TABLE 6.10A

ASPHALT PAVING INDUSTRY
EMISSION RATES REQUIRED TO SATISFY ALTERNATIVE ABATEMENT LEVELS
(SIC 3699)

Alternative Abatement Levels	Emission Factor Requirements (Kg of Emissions/ Tonne of Product Output)
Existing	.03
3	.02
2	.015
1	.01

TABLE 6.10B

ASPHALT PAVING INDUSTRY
CONTROL SYSTEMS REQUIRED
TO SATISFY ALTERNATIVE ABATEMENT LEVELS
(SIC 3699)

Plant Types	Abatement Level			
	Existing	3	2	1
	Alternative Control Systems			
Permanent	Baghouse	Baghouse	Baghouse	Baghouse
Portable	Venturi	HE Venturi	Baghouse	Baghouse
	Baghouse	Baghouse	Baghouse	Baghouse

TABLE 6.11A

PETROCHEMICAL PRODUCTS INDUSTRY EMISSION RATES TO SATISFY ALTERNATIVE ABATEMENT LEVELS

(kg/tonne product)

SIC Code & Manufacturing Process	Emission	Abatement Level			
		Existing	3	2	1
3712 Organic Chemical Industry					
PVC	Particulates	3.8	3.8	3.8	3.8×10^{-1}
	SO_2	1.3×10^{-2}	1.3×10^{-2}	3.9×10^{-3}	3.9×10^{-3}
	NO_x	100	100	100	44
	VOC	8.5	8.5	8.5	8.5×10^{-1}
Vinyl Chloride	Particulates	17.5	17.5	17.5	1.8
	SO_2	1.3×10^{-2}	1.3×10^{-2}	3.9×10^{-3}	3.9×10^{-3}
	NO_x	44.7	44.7	44.7	19.6
	VOC	8.5	8.5	8.5	8.5×10^{-1}
HD/HL Polyethylene	Particulates	1.1	1.1	1.1	1.1×10^{-1}
Ethylene, Propylene	NO_x	2.5×10^{-1}	2.5×10^{-1}	2.5×10^{-1}	4.6×10^{-2}
Xylene, Toluene	VOC	11.4	11.4	2.3	2.3
Benzene	Particulates	3.4×10^{-1}	3.4×10^{-1}	1.7×10^{-3}	3.4×10^{-4}
	VOC	1.4×10^{-1}	1.4×10^{-1}	1.4×10^{-1}	2.8×10^{-2}
Styrene	Particulates	3.3×10^{-1}	3.3×10^{-1}	1.7×10^{-3}	3.3×10^{-4}
	VOC	29.8	29.8	1.5	3.0×10^{-1}
Styrene Acryl	Particulates	4.2	4.2	2.1×10^{-1}	4.2×10^{-2}
Butadiene	VOC	55.2	55.2	55.2	5.5×10^{-1}
3731 - Plastics and Synthetic Resins	VOC	35.0	3.5×10^{-3}	3.5×10^{-3}	3.5×10^{-3}
3751 - Paint & Varnish					
Paint	Particulates	.06	.05	3.0×10^{-4}	6.0×10^{-5}
	VOC	2.75	2.75	1.4×10^{-2}	3.0×10^{-3}
Varnish	VOC	75	75	3.8×10^{-1}	8.0×10^{-2}
3791 - Printing Ink					
Solvent	VOC	.54	.54	0.03	0.02
Pigment	Particulate	.003	0.01	0.002	0.0002
3792 - Adhesive Industries	VOC	.03	6.0×10^{-4}	6.0×10^{-4}	6.0×10^{-4}
3799 - Other Chemicals					
Metallic Additives	Pb	0.3	0.3	0.2	0.031
Pigment, Acrylics, Sludges	Particulates	33.1	24.8	16.5	8.3
Plasticizer &	NO_x	1.1	1.1	1.1	0.73
Solvent Reclamation	VOC	58.4	43.7	6	3
SIC 9721 - Dry Cleaning					
Partial Solvent Recovery	Perchlorethalene	1.85	0.93	0.0	0.0

TABLE 6.11B

PETRO CHEMICAL PRODUCTS INDUSTRY
CONTROL SYSTEMS REQUIRED TO SATISFY
ALTERNATIVE ABATEMENT LEVELS

		Abatement Level			
	Emission	Existing	3	2	1
3712 Organic Chemical Industry					
PVC					
	PM	- Baghouse	- Baghouse	- Baghouse	- Baghouse
	VOC	- Wet Scrubbing - Solvent & Adsorber and Backup Incineration - Steam Stripping	- Wet Scrubbing - Solvent & Adsorber and Backup Incineration - Steam Stripping	- Wet Scrubbing - Solvent & Adsorber and Backup Incineration - Steam Stripping	- Solvent & Adsorber and Afterburner (99.99 Eff.)
	NO_x	- Low NO_x Burners	- Low NO_x Burners	- Low NO_x Burners	- Selective Catalytic Reduction (65% Eff)
	SO_2	- Uncontrolled (UC)	- UC	- Low S fuel/gas	- Low S fuel/gas
Vinyl Chloride	PM	- Baghouse	- Baghouse	- Baghouse	- Baghouse
	VOC	- Incineration (89% Eff)	- Incineration	- Incineration	- Solvent Adsorbers and Incineration (99.9% Efficiency)
	NO_x	- Low NO_x Burners	- Low NO_x Burners	- Low NO_x Burners	- Selective Catalytic Reduction (65% Eff)
	SO_2	- UC	- UC	- Low S fuel/gas	- Low S fuel/gas
Organic Solvents and Gases	PM	- Baghouse	- Baghouse	- Baghouse	- Baghouse (99.9% Efficiency)
	VOC	- Carbon adsorption - Incineration (99.5% Eff)	- Carbon adsorption - Incineration (99.5% Eff)	- Catalytic Activator (99.9%)	- Catalytic Activator (99.9%)
	NO_x	- Low NO_x Burners	- Low NO_x Burners	- Low NO_x Burners	- Selective Catalytic Reduction (65% Eff)
Benzene	PM	- UC	- UC	- Baghouse	- Baghouse
	VOC	- Carbon adsorption - Incineration (99.5% Eff)	- Carbon adsorption - Incineration (99.5% Eff)	- Carbon adsorption - Incineration (99.5% Eff)	- Carbon adsorption - Incineration (99.5% Eff)
Styrene	PM	- UC	- UC	- Baghouse	- Baghouse
	VOC	- Steam Stripping and Condenser (90%)	- Steam Stripping and Condenser (90%)	- Solvent Adsorber (99.5%)	- Solvent adsorber and Incineration (99.9%)
Styrene Acryl	PM	- UC	- UC	- Baghouse	- Baghouse
Butediene	VOC	- Flare (90%) - Steam Stripper (90%) - Butadiene Adsorber (90%)	- Flare (90%) - Steam Stripper (90%) - Butadiene Adsorber (90%)	- Flare (90%) - Steam Stripper (90%) - Butadiene Adsorber (90%)	- Solvent Adsorber (99.9%)

TABLE 6.11B (Continued)

		Abatement Level			
	Emission	Existing	3	2	1
3731 - Plastics and Synthetic Resins					
Fibreglass	VOC	- Dispersion	- Incineration	- Incineration	- Incineration
3751 - Paint & Varnish					
Paint Mixing	Particulate	- Baghouse	- Baghouse	- Baghouse Afterburner Absolute Filter Wet Scrubber	- Baghouse Afterburner Absolute Filter Wet Scrubber
Paint Packaging	VOC	- UC	- UC	- Afterburner	- Afterburner
Varnish	VOC	- UC	- UC	- Afterburner	
3791 - Printing Ink					
	Particulate	- Baghouse	- Baghouse	- Baghouse	- Baghouse
		- Roto-clone	- Baghouse	- Baghouse	- Baghouse
	VOC	- UC Venturi	- Scrubber - Scrubber	- Scrubber & Afterburner	- Condenser & Afterburner
3792 - Adhesives Industries	VOC	- Condensers and carbon filter	- Scrubber	- Scrubber Incinerator	- Scrubber Incinerator
3799 - Other Chemicals Industry					
Metallic Additives	Pb	- Baghouse	- ME Baghouse	- HE Baghouse	- HE Baghouse
Pigment, Acrylics, Sludges	Particulates	- Baghouse	- ME Baghouse	- HE Baghouse	- HE Baghouse
Plasticizer & Solvent Reclamation	NO$_x$ VOC	- UC	- Catalytic Incinerator	- HE Catalytic Incinerator	- Thermal Incinerator
SIC 9721 - Dry Cleaning					
Partial Solvent Recovery			- Carbon Adsorber & Condensers & Better Maintenance	- Closed System	- Closed System
Complete Solvent Recover		- Closed System	- Closed System	- Closed System	- Closed System

TABLE 6.12A

ELECTRIC POWER GENERATION

EMISSION RATES REQUIRED TO SATISFY ALTERNATIVE ABATEMENT LEVELS
(Tonnes/Million MWh at Rated Capacity)

	Abatement Level			
Plant	Existing	3	2	1
Bituminous Fired				
. Lakeview	242	300	93	≤ 47
. Lambton	349	300	93	≤ 47
. Nanticoke	214	300	93	≤ 47
Lignite Fired				
. Thunder Bay	139	335	103	≤ 52
. Atikokan	150	316	97	≤ 49
Oil Fired				
. Lennox	23	23	23	≤ 23[1]

Note:

[1] The emission rate of 1 for an oil-fired generating station is in the order of 319 tonnes per million MWh of power production. The existing electrostatic precipitators at the station limit emission rates to 23 tonnes per million MWh.

TABLE 6.12B

ELECTRIC POWER GENERATION

CONTROL SYSTEMS REQUIRED TO SATISFY ALTERNATIVE ABATEMENT LEVELS

Station	Abatement Level			
Type	Existing	3	2	1
Bituminous Fired				
. Lakeview	ESP	ESP	ESP & Baghouse	Baghouse
. Lambton	ESP	ESP	ESP & Baghouse	Baghouse
. Nanticoke	ESP	ESP	ESP & Baghouse	Baghouse
Lignite Fired				
. Thunder Bay	ESP	ESP	ESP & Baghouse	Baghouse
. Atikokan	ESP	ESP	ESP & Baghouse	Baghouse
Oil Fired				
. Lennox	ESP	ESP	ESP	ESP

Note:

Electrostatic Precipitator (ESP)

TABLE 6.13A

WASTE DISPOSAL INDUSTRY
EMISSION RATES REQUIRED TO SATISFY
ALTERNATIVE ABATEMENT LEVELS

Waste Disposal/Abatement Types Level	Odour units/ft^3	Emission(kg/tonne) PM	SO_2	NO_x	HCl	Pb	Hg	Cd	Cr	PCDD	PCDF	PCB	THC	CH_4	ROG*	CO	Org. Alds.	Aldehydes
Transfer Stations																		
Existing	50																	
Level 3	50																	
2	4.5																	
1	NA																	
Municipal Waste Incineration																		
Semi-suspension Incinerator (kg/tonne waste)																		
Existing		1.6	2.0	1.2	3.8	1.6×10^{-2}	1.2×10^{-3}	1.0×10^{-2}	4.0×10^{-3}	7.3×10^{-6}	1.5×10^{-5}	1.3×10^{-3}						
Level 3		1.6	2.0	1.2	3.8	1.6×10^{-2}	1.2×10^{-3}	1.0×10^{-2}	4.0×10^{-3}	7.3×10^{-6}	1.5×10^{-5}	1.3×10^{-3}						
2		1.6	0.6	1.2	0.8	1.6×10^{-2}	1.2×10^{-3}	1.0×10^{-2}	4.0×10^{-3}	7.3×10^{-6}	1.5×10^{-5}	1.3×10^{-3}						
1		1.6	0.6	0.7	0.8	1.6×10^{-2}	1.2×10^{-3}	1.0×10^{-2}	4.0×10^{-3}	7.3×10^{-6}	1.5×10^{-5}	1.3×10^{-3}						
Multi-chamber Incinerator																		
Existing		4.2	0.4	1.5	0.5	3.5×10^{-4}	1.2×10^{-4}	1.3×10^{-2}	6.6×10^{-4}	4.0×10^{-7}	6.0×10^{-7}	3.5×10^{-3}						
Level 3		4.2	0.4	1.5	0.5	3.5×10^{-4}	1.2×10^{-4}	1.3×10^{-2}	6.6×10^{-4}	4.0×10^{-7}	6.0×10^{-7}	3.5×10^{-3}						
2		4.2	0.4	1.5	0.5	3.5×10^{-4}	1.2×10^{-4}	1.3×10^{-2}	6.6×10^{-4}	4.0×10^{-7}	6.0×10^{-7}	3.5×10^{-3}						
1		4.2	0.3	0.9	0.2	7.0×10^{-5}	1.2×10^{-4}	2.6×10^{-3}	1.3×10^{-4}	8.0×10^{-8}	1.2×10^{-7}	7.0×10^{-4}						
Commercial & Industrial Incineration																		
Existing		6.0×10^{-2}	5.0×10^{-1}	1.5		5.0×10^{-4}	3.0×10^{-3}						3.0×10^{-1}			2.2		
Level 3		6.0×10^{-2}	5.0×10^{-1}	1.5		5.0×10^{-4}	3.0×10^{-3}						3.0×10^{-1}			2.2		
2		6.0×10^{-2}	5.0×10^{-1}	1.1		5.0×10^{-4}	3.0×10^{-3}						3.0×10^{-1}			2.2		
1		6.0×10^{-3}	5.0×10^{-1}	0.9		5.0×10^{-5}	3.0×10^{-3}						3.0×10^{-1}			2.2		
Sewage Sludge Incinerator																		
Multihearth Incinerator (kg/tonne dry waste)																		
Existing		1.3	5.0×10^{-1}	6.0	1.5×10^{-1}	8.0×10^{-3}							5.0×10^{-1}					
Level 3		5.0×10^{-1}	4.0×10^{-1}	2.5	1.5×10^{-1}	4.0×10^{-4}							5.0×10^{-1}					
2		2.5×10^{-1}	3.0×10^{-1}	1.9	1.0×10^{-1}	2.0×10^{-4}							5.0×10^{-1}					
1		2.5×10^{-1}	3.0×10^{-1}	1.5	1.0×10^{-1}	2.0×10^{-4}							5.0×10^{-1}					
Fluidized Bed Incinerator																		
Existing		9.0×10^{-1}	2.4×10^{-1}	1.3	1.5×10^{-1}	4.0×10^{-4}							5.0×10^{-1}					
Level 3		5.0×10^{-1}	4.0×10^{-1}	2.5	1.5×10^{-1}	4.0×10^{-4}							5.0×10^{-1}					
2		2.5×10^{-1}	3.0×10^{-1}	1.9	1.0×10^{-1}	2.0×10^{-4}							5.0×10^{-1}					
1		2.5×10^{-1}	3.0×10^{-1}	1.5	1.0×10^{-1}	2.0×10^{-4}							5.0×10^{-1}					
Hospital Waste Incineration																		
Existing		1.14		6.1×10^{-1}													7.5×10^{-1}	4.9×10^{-1}
Level 3		5.0×10^{-1}		6.1×10^{-2}													7.5×10^{-2}	4.9×10^{-2}
2		1.0×10^{-2}		6.1×10^{-3}													7.5×10^{-3}	4.9×10^{-3}
1		5.0×10^{-3}		3.1×10^{-3}													3.8×10^{-3}	2.5×10^{-3}
Landfill																		
Existing														1.96	.0203			
Level 3														1.96	.0203			
2														.06	.0009			
1														.04	.0006			

TABLE 6.13B

WASTE DISPOSAL INDUSTRY CONTROL SYSTEMS REQUIRED TO SATISFY ALTERNATIVE ABATEMENT LEVELS

Waste Disposal Facilities	Abatement Level			
	Existing	3	2	1
Municipal Waste Disposal				
Transfer Stations	Odour Suppressants Spray	Odour Suppressants Spray	Odour Scrubbers	Odour Scrubbers
Landfill	UC, Passive Ventillation Active Ventillation Gas Recovery & Incineration	Active Ventillation	Gas Gathering & Incineration	Gas Gathering & Incineration
Municipal Waste Incineration				
Multichamber Incinerator	Lime Injection & Baghouse	Lime Injection & Baghouse	Quench, Lime Injection & Baghouse	Excess Lime Injection & Baghouse Thermal De Nox
Semi-suspension Incinerator	Quench and Baghouse	Quench and Baghouse	Quench, Lime Injection & Baghouse	Excess Lime Injection & Baghouse, Thermal De Nox
Sewage Sludge				
Multihearth Incinerator	Wet Scrubber	Venturi Scrubber	Baghouse Lime Injection & Baghouse, FGR Air Control	Baghouse Lime Injection & Baghouse, Thermal De Nox
Fluidized Bed Incinerator	Venturi Scrubber	Venturi Scrubber	Option 1 Venturi Option 2 Lime Injection & Baghouse	Baghouse, Lime Injection & Baghouse, Thermal De Nox
Private Waste Disposal				
Commercial & Industrial Incineration	Dry Lime Injection & Baghouse	Dry Lime Injection & Baghouse	Dry Lime Injection & Baghouse FGR	Dry Lime Injection & Baghouse, Thermal De Nox
Institutional Waste Disposal				
Hospital Waste Incineration	Incinerator	Pathological Incinerator	Pathological Incinerator	Pathological Incinerator

7.0 ALTERNATIVE ABATEMENT SCENARIOS: INDUSTRY COSTS AND EMISSIONS

7.1 Introduction

This chapter presents capital and annual operating cost estimates for alternative abatement Levels 3, 2, and 1 by process within each sector. Using these costs, estimates have been prepared for the five scenarios described in Chapter 2 and as set out in Table 2.2.

The estimated capital and operating costs would result if existing industrial and municipal facilities were to be retrofitted with the control systems necessary to meet the contaminant abatement levels prescribed in each of the scenarios shown in Table 2.2. The emissions generated for each scenario are also presented. They are given by contaminant for each process and are presented for each level of abatement identified in Table 2.2. The following subsections deal with each sector separately.

7.2 Sector Description

7.2.1 Open Pit Mining (SIC 0611 and 0617)

Capital and operating cost estimates by alternative abatement level are presented in Tables 7.1A and 7.1B. Scenario costs are presented in Table 7.1C which show potential costs to be highest for Scenarios A and B. The reductions in emissions are presented in Table 7.1D. A reduction of approximately 45% is achieved for all abatement scenarios except C.

The costs are those needed to install each piece of control equipment from zero. They do not imply step-wise control.

7.2.2 Food Industry (SIC 1011, 1012, 1021, 1049, 9211, 9212 and 9213)

Estimates of capital and operating costs for alternative abatement levels are presented in Tables 7.2A and 7.2B. Scenario costs are presented in Table 7.2C which shows costs to be highest for Scenario B. Reductions in air emissions are presented in Table 7.2D. Depending on contaminant, reduction of 88% to 99% would be achieved for all scenarios except C.

7.2.3 Pulp and Paper and Allied Products (SIC 2711, 2712, 2713, 2811, 2819, 2821, 2841, 2849)

Capital and operating cost estimates by alternative abatement level are presented in Tables 7.3A and 7.3B. Scenario costs presented in Table 7.3C show highest potential costs for Scenario B. The reduction in emissions are presented in Table 7.3D.

Significant reductions in particulate matter, acid gases and VOC would be achieved under the alternative abatement scenarios.

7.2.4 Iron and Steel Industry (SIC 2911, 2912, 2919)

Capital and operating cost estimates are presented in Tables 7.4A and 7.4B by alternative abatement levels. Scenario costs are presented in able 7.4C which shows comparable costs for Scenarios A, B, D and phase 1 of E. Reductions in air emissions are presented in Table 7.4D. For all scenarios except C, the reduction in particulates would be about 50%.

7.2.5 Foundry Industries (SIC 2941, 2971 , 2999)

Capital and operating cost estimates are presented in Table 7.5A and 7.5B for alternative abatement levels. Scenario costs presented in Table 7.5C, show comparable costs for Scenarios A, B, D and E. Costs for Scenario C are slightly lower. Reductions in air emissions are presented in Table 7.5D. For Scenarios A, B, D and E, particulates would be reduced by about 90% whereas for Scenario C the reduction would be less, about 75%.

7.2.6 Non-Ferrous Smelters and Refiners (SIC 2959)

Capital and operating cost estimates are presented in Tables 7.6A and 7.6B for alternative abatement levels. Scenario costs presented in Table 7.6C show comparable costs for Scenarios A, B, and D. Reductions in air emission are presented in Table 7.6D. For Scenarios A, B and D, particulates and heavy metals are reduced by over 90%.

7.2.7 Automotive Industry (SIC 3231, 3254, 3255, 3259)

Capital and operating cost estimates by alternative abatement levels are presented in Tables 7.7A and 7.7B. Scenario costs are presented in Table 7.7C,. Reductions in air emissions are presented in Table 7.7D. For Scenarios A,B, D and E, annual VOC emissions are reduced by about 50% and for Scenario C about 30%. Lead is reduced by about 90% in scenario C and about 95% in the other scenarios. Asbestos remains unchanged, except in Scenario B, where there is an 80% reduction. Talc emissions remain unchanged for all scenarios. The "other particulates" are reduced by almost 90% in scenario B but remain unchanged for the remaining scenarios.

7.2.8 Inorganic Chemical Manufacturing Industry (SIC 3511, 3512, 3521, 3571, 3581, 3711, 3721)

Capital and operating cost estimates by alternative abatement levels are presented in Tables 7.8A and 7.8B. Costs presented in Table 7.8C, show comparable costs for Scenarios A and B. Reductions in air emissions are presented in Table 7.8D. For Scenarios A, B, D and E, particulate emissions are reduced by 77%. VOCs are reduced by 50% for all scenarios. Sulphur dioxide emissions decrease by 50% for most SIC categories in all the scenarios. Fluoride is reduced by 98% for Scenarios A, B, C and E and by 75% in Scenario C.

The reduction of nitrogen oxides (NO_x) varies for each SIC category in the alternative abatement scenarios.

7.2.9 Petroleum Refining Industry (SIC 3611)

Capital and operating cost estimates by alternative abatement levels are presented in Tables 7.9A and 7.9B. Scenario costs presented in Table 7.9C show the highest total abatement costs for Scenario B and the lowest costs for Scenario D. Reductions in air emissions are shown in Table 7.9D. The greatest reduction for SO_2 is 67% in Scenario B. The reduction for nitrogen oxides is greatest for Scenario B (53%), and the reduction for particulates is the same for Scenarios A, B, and D, about 76%. VOCs are lowest for Scenario B with a reduction of approximately 34%.

7.2.10 Asphalt Paving Industry (SIC 3699)

Capital and operating cost estimates by alternative abatement levels are presented in Tables 7.10A and 7.10B. Scenario costs presented in Table 7.10C are the same for scenarios A, B, D and E. For scenario C, they are lower. Reductions in air emissions shown in Table 7.10D show only small decreases in particulate emissions.

7.2.11 Petrochemical Products Industry (SIC 3712, 3731, 3751, 3791, 3792, 3799, 9721)

Capital and operating cost estimates by alternative abatement levels are presented in Tables 7.11A and 7.11B. Scenario costs presented in Table 7.11C show lowest total abatement cost for scenario C, with the other scenarios having comparable costs. Reductions in air emissions are shown in Table 7.11D. Particulate matter reduction is lowest at 19% for scenario C while the remaining scenarios show a 73% reduction. VOCs including perchloroethalene are reduced by 90% for all scenarios. Lead is reduced by 90% for all scenarios except for scenario C, in which it is reduced by 33%.

7.2.12 Electric Power Generation (SIC 4911)

Capital and operating cost estimates by alternative abatement levels are presented in Tables 7.12A and 7.12B. Scenario costs are presented in Table 7.12C. Scenarios C and E (Phase 1) have no capital costs and therefore have the lowest total costs. Reductions in air emissions are shown in Table 7.12D. Scenario B exhibits the greatest reduction in particulate air emissions at 78%. Scenarios C and E (Phase 1) show no changes in particulate emissions from the existing scenario.

7.2.13 Waste Disposal Industry

Capital and operating cost estimates for alternative abatement levels are presented in Tables 7.13A and 7.13B. Scenario costs shown in Table 7.13C are lowest for Scenario C and highest for Scenario B. Reductions in air emissions are shown in Table 7.13D. The reductions for particulates are 28% in all scenarios. There is a 99% reduction for organic acids in all scenarios. Nitrogen oxides are reduced by 41% in Scenario C and by about 60% in the other scenarios. Methane emissions are reduced by 97% for Scenario C and 98% for all other scenarios. Reactive organic gases (ROG) are reduced by 94% for Scenario C and 99% for the other scenarios. The emissions of SO_2 are reduced by about 53% for all scenarios. Hydrogen chloride reduction is about 75% for all scenarios. The amount of lead emitted is reduced by about 29% for all scenarios. There is no reduction of mercury. Scenario C had no reduction in cadmium emissions. In the other scenarios, cadmium is reduced by 35%. Chromium was not reduced in Scenario C, but was reduced by 14% for the other scenarios. Polychlorinated dibenzo dioxins (PCDD) and polychlorinated dibenzo furans (PCDF) were not reduced for any of the scenarios. The amount of polychlorinated biphenols (PCB's) was not reduced for Scenario C, but in the other scenarios, it was reduced by 60%. Finally, aldehydes were reduced by about 98% in Scenario C and 99.6% for the other scenarios.

TABLE 7.1A

OPEN PIT MINING
CAPITAL COSTS FOR EQUIPMENT
REQUIRED TO MEET
ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

	SIC	Abatement Level	
Mine Type	Code	3	2 & 1
Gold	0611	$.4	$.6
Iron	0617	$.2	$.3

TABLE 7.1B

OPEN PIT MINING
ANNUAL OPERATING COSTS FOR EQUIPMENT
REQUIRED TO MEET
ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

	SIC	Abatement Level	
Mine Type	Code	3	2 & 1
Gold	0611	$.4	$3.6
Iron	0617	$.2	$1.8

TABLE 7.1C

OPEN PIT MINING

ABATEMENT COSTS

(Millions of 1986 $'s)

Sectors	S.I.C. Code	Existing Annual Operating	Scenario A Capital	Annual Operating	Scenario B Capital	Annual Operating	Scenario C Capital	Annual Operating	Scenario D Capital	Annual Operatin
Gold	0611	$0.2	$0.6	$3.6	$0.6	$3.6	$0.4	$0.4	$0.6	$3.6
Iron	0617	$0.1	$0.3	$1.8	$0.3	$1.8	$0.2	$0.2	$0.3	$1.8
TOTAL		$0.3	$0.9	$5.4	$0.9	$5.4	$0.6	$0.6	$0.9	$5.4

TABLE 7.1D

OPEN PIT MINING
ANNUAL EMISSIONS GENERATED
UNDER ALTERNATIVE ABATEMENT SCENARIOS
AT RATED CAPACITY

Alternative Abatement Scenarios	S.I.C. Code	Particulate (tonnes/year)
Existing	0611	4,418
	0617	2,857
A	0611	2,945
	0617	1,978
B	0611	2,945
	0617	1,978
C	0611	3,577
	0617	2,308
D	0611	2,945
	0617	1,978
E	0611	2,945
	0617	1,975

TABLE 7.2A

FOOD INDUSTRY
CAPITAL COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

SIC Code & Manufacturing Processes	Abatement Level		
	3	2	1
1011 - Meat & Meat Products			
Slaughter Houses	--	$16.1	$16.1
Rendering	--	$ 3.8	$ 3.8
Processing	--	--	$51.9
		$19.9	$71.8
1012 - Poultry & Poultry Products			
Slaughter Houses	--	$ 4.2	$ 8.4
Rendering	--		
Processing	--	--	$ 1.2
			$ 9.6
1021 - Fish Products Processing	--	$ 1.2	$ 2.4
1049 - Other Dairy			
Cheese	--	$ 5.6	$ 5.6
Skim Milk Powder	--	--	--
Evaporated Milk	--	--	--
9211 9212 Restaurants 9213	--	$ 4.5	$ 4.5

TABLE 7.2B

FOOD INDUSTRY
ANNUAL OPERATING COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

SIC Code & Manufacturing Processes	Abatement Level		
	3	2	1
1011 - Meat & Meat Products			
Slaughter Houses	$ .8	$ .8	$ .8
Rendering	$ .2	$ .2	$ .2
Processing	$2.52	$2.52	$2.52
	$3.5	$3.5	$3.5
1012 - Poultry & Poultry Products			
Slaughter Houses	$ .43	$ .43	$ .43
Rendering			
Processing	$ .06	$ .06	$ .06
	$ .5	$ .5	$ .5
1021 - Fish Products			
Processing	$ --	$ .24	$ .24
1049 - Other Dairy			
Cheese	$ .33	$ .65	$ .65
Skim Milk Powder	$ .33	$ .33	$ .33
Evaporated Milk	$ .09	$ .09	$ .09
	$ .8	$1.07	$1.07
9211			
9212 Restaurants	--	$ .29	$ .29
9213			

TABLE 7-2C

Abatement Costs
Food
(Millions of 1986 $'s)

Sectors	Existing		Scenario A		Scenario B		Scenario C		Scenario D		Scenario E Phase 1		Scenario E Phase 2
	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating
Meat Products [1011]	$3.5	$71.8	$3.5	$71.8	$3.5	$0.0	$3.5	$71.8	$3.5	$51.9	$3.5	$19.9	$3.5
Poultry Products [1012]	$0.0	$5.4	$0.5	$9.6	$0.5	$0.0	$0.5	$5.4	$0.5	$1.2	$0.1	$4.2	$0.5
Fish Products [1021]	$0.0	$2.4	$0.2	$2.4	$0.2	$1.2	$0.2	$2.4	$0.2	$2.4	$0.2	$0.0	$0.2
Dairy [1049]	$0.3	$5.6	$1.1	$5.6	$1.1	$5.6	$1.1	$5.6	$1.1	$5.6	$1.1	$0.0	$1.1
Restaurants [9211,9212,9213]	$0.0	$4.5	$0.3	$4.5	$0.3	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$4.5	$0.3
Total	$3.8	$89.7	$5.6	$93.9	$5.6	$6.8	$5.3	$85.2	$5.3	$61.1	$4.9	$28.6	$5.6

TABLE 7.2D

FOOD INDUSTRY ANNUAL EMISSIONS GENERATED UNDER ALTERNATIVE ABATEMENT SCENARIOS AT RATED CAPACITY

Alternative Abatement Scenarios		Annual Emissions		
		Particulates (tonnes)	VOC's (tonnes)	Odour Units (ou/min/facility)
Existing	1011	5.3	6.3	$1x10^{10}$
	1012	1.2	1.4	$2x10^{9}$
	1021	.1	.1	
	1049	19.4		
	9211,9212,9213			$6x10^{9}$
A	1011	.4	.7	$9x10^{6}$
	1012	.1	.2	$9x10^{6}$
	1021	neg.	neg.	
	1049	.1		
	9211,9212,9213			$6x10^{6}$
B	1011	.4	.7	$5x10^{6}$
	1012	.1	.2	$5x10^{6}$
	1021	neg.	neg.	
	1049	.1		
	9212			$6x10^{6}$
C	1011	1	2.1	$1x10^{10}$
	1012	.2	.5	$2x10^{9}$
	1021	neg.	neg.	
	1049	.1		
	9212			$6x10^{9}$
D	1011	.4	.7	$9x10^{6}$
	1012	.1	.2	$9x10^{6}$
	1021	neg.	neg.	
	1049	.1		
	9212			$6x10^{6}$
E	1011	.4	.7	$1x10^{10}$
	1012	.1	.2	$2x10^{9}$
	1021	neg.	neg.	
	1049	.1		
	9211			$6x10^{9}$
	9212			$6x10^{9}$
	9213			$6x10^{9}$

TABLE 7.3A

PULP AND PAPER AND ALLIED PRODUCTS
CAPITAL COSTS FOR EQUIPMENT
REQUIRED TO MEET ALTERNATIVE
ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

SIC Code & Manufacturing Processes	Abatement Level		
	3	2	1
2711 - Kraft Pulp Mills			
. Recovery Boiler	$22.5	$25.2	$31.5
. Lime Kiln	2.03	2.7	3.6
. Smelt Tank	1.13	1.8	1.8
. Bleach Plant	7.2	7.43	16.0
. Boilers	--	--	.2
	$32.9	$37.1	$53.1
2712 - Newsprint Mills w/Kraft Pulp			
. Recovery Boiler	$9.0	$10.1	$12.4
. Lime Kiln	.8	1.0	1.4
. Small Tanks	.4	.7	.7
. Bleach Plant	2.8	3.0	6.1
. Boilers	--	--	.8
	$13	$14.8	$21.4
- Newsprint Mills w/Sulphite Pulping			
. Blowpit Stack	$5.1	$5.6	$7.2
. Acid Plant	5.1	5.6	7.2
. Steam Boilers	1.6	1.7	3.5
	$11.8	$12.9	$17.9

TABLE 7.3A (Continued)

SIC Code & Manufacturing Processes	Abatement Level		
	3	2	1
- Newsprint Mills w/Groundwood Pulping			
. Steam Boilers	$1.5	$1.6	$3.2
- Newsprint Mills			
. Steam Boilers	$1.5	$1.5	$3.2
2713 - Paperboard Mills w/Kraft Pulping			
. Recovery Boiler	$3.5	$3.9	$4.9
. Lime Kiln	.3	.4	.5
. Smelt Tank	.2	.2	.2
. Bleach Plant	.03	.03	.03
. Boilers	1.1	1.1	2.4
	$5.1	$5.6	$8.0
- Paperboard Mills w/ Semi-Chemical Pulping			
. Steam Boilers	$.2	$.2	$.4
- Paperboard Mills			
. Steam Boilers	$.1	$.1	$.1

TABLE 7.3A (Continued)

SIC Code & Manufacturing Processes	Abatement Level		
	3	2	1
2811 - Business Forms Industry	--	$3.8	$4.7
2819 - Other Commercial Printing Industry	--	$45.5	$52.7
2821 - Plate Making, Type Setting and Binding Industry	$17.6	$25.1 (1)	$24.0
2841 - Magazines and Newspaper Industry	$6.9	$16.9	$16.1
2849 - Other Combined Publishing Printing Industry			
. Wallpaper	--	--	--
. Other	$1.5	$1.9	$1.8

Note:

(1) High efficiency is more expensive.
Actual costs will vary from plant-to-plant. If Level 2 is imposed by the MOE, some plants will go to Level 1 and some will go to Level 2; thus, the maximum reduction in costs is likely to be achieved.

TABLE 7.3B

PULP AND PAPER AND ALLIED PRODUCTS
ANNUAL OPERATING COSTS FOR EQUIPMENT
REQUIRED TO MEET ALTERNATIVE
ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

SIC Code & Manufacturing Processes	Abatement Level			
	Existing	3	2	1
2711 - Kraft Pulp Mills				
. Recovery Boiler	$ 0.36	$ 0.43	$ 0.45	$ 0.50
. Lime Kiln	1.04	1.04	1.08	1.15
. Smelt Tank	0.88	0.88	0.92	0.92
. Bleach Plant	0.23	0.23	0.23	0.23
. Boilers	3.04	3.04	3.04	3.51
	$ 5.6	$ 5.6	$ 5.7	$ 6.3
2712 - Newsprint Mills w/Kraft Pulp				
. Recovery Boiler	$ .14	$ .17	$ .17	$ .19
. Lime Kiln	.41	.41	.43	.45
. Smelt Tanks	.35	.35	.36	.37
. Steam Boilers	1.19	1.19	1.19	1.36
. Bleach Plant	.09	.09	.09	.09
	$ 2.2	$ 2.2	$ 2.2	$ 2.5
- Newsprint Mills w/Sulphite Pulping				
. Blowpit Stack	$ .08	$ .09	$ .1	$ .11
. Acid Plant	.08	.09	.1	.11
. Steam Boilers	.66	.66	.66	.77
	$ .8	$ .8	$ .9	$ 1.0

TABLE 7.3B (Continued)

SIC Code & Manufacturing Processes	Abatement Level			
	Existing	3	2	1
- Newsprint Mills w/Groundwood Pulping				
. Steam Boilers	$ .66	$ .66	$ .66	$ .77
- Newsprint Mills				
. Steam Boilers	$ .7	$ .7	$ .7	$ .8
2713 - Paperboard Mills w/Kraft Pulping				
. Recovery Boiler	$ .06	$ .07	$ .07	$ .08
. Lime Kiln	.16	.16	.17	.18
. Smelt Tank	.14	.14	.14	.14
. Bleach Plant	.47	.47	.47	.54
. Boilers	.03	.03	.03	.03
	$ .9	$ .9	$ .9	$ 1.0
- Paperboard Mills w/ Semi-Chemical Pulping				
. Steam Boilers	$ .1	$ .1	$ .1	$ .1
- Paperboard Mills	$ .01	$ .01	$ .01	$ .01
. Steam Boilers				

TABLE 7.3B (Continued)

SIC Code & Manufacturing Processes	Abatement Level			
	Existing	3	2	1
2811 - Business Forms Industry	UC	UC	$ .44	$ .23
2819 - Other Commercial Printing Industry	UC	UC	$ 5.5	$ 2.1
2821 - Plate Making, Type Setting and Binding Industry	$ .2	$ 2.4	$ 3.0(1)	$ 1.4
2841 - Magazines and Newspaper Industry	$ .8	$ 1.6	$ 2.0	$ 1.0
2849 - Other Combined Publishing Printing Industry				
. Wallpaper	$ .01	$ .01	$ .01	$ .01
. Other	UC	$ .18	$ .23	$ .11
	$ .01	$ .2	$ .2	$ .1

Note:

(1) High Efficiency is more expensive.
Actual costs will vary from plant-to-plant. If Level 2 is imposed by the MOE, some plants will go to Level 1 and some will go to Level 2; thus, the maximum reduction in costs is likely to be achieved.

Table 7.3C

Abatement Costs
Pulp & Paper & Allied Products
(Millions of 1986 $'s)

Sectors	Existing	Scenario A		Scenario B		Scenario C		Scenario D		Scenario E Phase 1		Scenario E Phase 2	
	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating
Kraft Pulp Mills [2711]	$5.6	$44.5	$6.3	$53.1	$6.3	$36.9	$5.9	$44.5	$6.3	$31.2	$4.4	$13.3	$6.3
Newsprint/Kraft Mills [2712]	$2.2	$17.5	$2.5	$21.4	$2.5	$14.6	$2.2	$17.5	$2.5	$12.6	$1.9	$4.9	$2.5
Newsprint/Sulphite [2712]	$0.8	$14.7	$1.0	$17.9	$1.0	$11.9	$0.9	$14.7	$1.0	$2.9	$0.2	$11.8	$1.0
Newsprint/Groundwood [2712]	$0.7	$3.2	$0.8	$3.2	$0.8	$1.6	$0.7	$3.2	$0.8	$3.2	$0.8	$0.0	$0.8
Newsprint Mills [2712]	$0.7	$3.5	$0.8	$3.5	$0.8	$1.7	$0.7	$3.5	$0.8	$3.5	$0.8	$0.0	$0.8
Sub Total [2712]	$4.4	$38.9	$5.1	$46.0	$5.1	$29.8	$4.5	$38.9	$5.1	$22.2	$3.7	$16.7	$5.1
Paperboard/Kraft [2713]	$0.9	$8.0	$0.9	$8.0	$1.0	$5.6	$0.9	$8.0	$0.9	$7.9	$0.9	$0.0	$0.9
Paperboard/Chemical [2713]	$0.1	$0.4	$0.1	$0.4	$0.1	$0.2	$0.1	$0.4	$0.1	$0.4	$0.1	$0.0	$0.1
Paperboard Mills [2713]	$0.1	$0.5	$0.1	$0.5	$0.1	$0.3	$0.1	$0.5	$0.1	$0.5	$0.1	$0.0	$0.1
Sub Total [2713]	$1.1	$8.9	$1.1	$8.9	$1.2	$6.1	$1.1	$8.9	$1.1	$8.8	$1.1	$0.0	$1.1
Business Forms [2811]	$0.0	$3.8	$0.4	$4.7	$0.2	$0.0	$0.0	$3.8	$0.4	$0.0	$0.0	$3.8	$0.4
Other Com Printing [2819]	$0.0	$44.1	$5.5	$51.1	$2.1	$0.0	$0.0	$44.1	$5.5	$0.0	$0.0	$44.1	$5.5
Plate Making [2821]	$0.2	$25.1	$3.0	$24.0	$1.4	$17.6	$2.4	$25.1	$3.0	$0.0	$0.2	$25.1	$3.0
Magazines & Newspapers [2841]	$0.8	$16.9	$2.0	$16.1	$1.0	$6.8	$1.6	$16.9	$2.0	$0.0	$0.8	$16.9	$2.0
Other Combined P&P [2849]	$0.0	$1.9	$0.2	$1.8	$0.1	$1.5	$0.2	$1.9	$0.2	$0.0	$0.0	$1.9	$0.2
Total	$12.1	$184.1	$23.6	$205.7	$17.4	$98.7	$15.7	$184.1	$23.6	$62.2	$10.2	$121.8	$23.6

TABLE 7.3D

PULP AND PAPER AND ALLIED PRODUCTS TOTAL EMISSIONS GENERATED UNDER ALTERNATIVE ABATEMENT SCENARIOS AT RATED CAPACITY

(tonnes/yr)

Alternative Abatement Scenarios	S.I.C. Code	Particulate Matter	Emissions					
			SO_2	NO_x	CO	Cl_2	ClO_2	VOCs
Existing	2711	6,893	9,730	2,869	6,374	567	189	
	2712	6,623	12,708	3,802	8,296	164	221	
	2713	5,568	1,398	1,242	3,744	81	2	
	2811							6,330
	2819							3,646
	2821							490
	2841							38,701
	2849							3,095
A	2711	927	2,194	1,362	6,374	567	189	
	2712	307	3,096	2,173	8,296	164	221	
	2713	2,030	781	1,096	3,744	81	2	
	2811							63
	2819							365
	2821							58
	2841							737
	2849							155
B	2711	927	2,194	1,362	6,374	284	95	
	2712	307	3,004	2,173	8,296	77	111	
	2713	2,030	781	1,096	3,744	42	2	
	2811							63
	2819							36.5
	2821							15
	2841							74
	2849							31
C	2711	1,391	9,730	2,869	6,374	284	95	
	2712	1,004	12,652	3,802	8,296	164	221	
	2713	2,476	1,398	1,242	3,744	81	2	
	2811							6,330
	2819							3,646
	2821							69
	2841							9,337
	2849							3,095
D	2711	927	2,194	1,362	6,374	567	189	
	2712	307	3,096	2,173	8,296	164	221	
	2713	2,030	781	1,096	3,774	81	2	
	2811							63
	2819							365
	2821							58
	2841							737
	2849							155
E	2711	927	9,730	2,869	6,374	567	189	
	2712	307	12,608	3,802	8,296	164	221	
	2713	2,030	1,398	1,242	3,744	81	2	
	2811							6,330
	2819							3,646
	2821							490
	2841							38,701
	2849							3,095

TABLE 7.4A

IRON AND STEEL INDUSTRY
CAPITAL COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY
($000,000)

SIC Code & Manufacturing Processes	Abatement Level 3	Abatement Level 2	Abatement Level 1
2911 Ferroalloy			
. Exothermic	--	$ .54	$ .54
2912 Steel Foundries			
. Coke Plants			
- Charging	UC	$78.4	$129.6
- Pushing	--	$78.4	$129.6
- Quenching	UC	UC	UC
- Flue Stacks	UC	$37.1	$51.2
. Blast & Open Hearth Furnace			
- Melting	--	--	--
- Heating	UC	UC	UC
- Dekishing	--	--	--
- Desulphuring	--	$ 9.8	$ 9.8
- Fugitive Emissions	$20.5	$76.7	$26.9
. Basic Oxygen Furnace			
- Charging	--	--	$43.2
- Tapping	--	--	--
- Transfer	--	--	--
- Melting & Refining	--	--	$28.9
- Fugitive Emissions	$20.5	$76.7	$26.9
2919 Other Primary Steel			
. Electric Arc	--	$ 2.3	$ 2.9
. Boilers Scarfing & Pits	$ .7	$ 1.5	$ 2.1

TABLE 7.4B

IRON AND STEEL INDUSTRY
ANNUAL OPERATING COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

SIC Code & Manufacturing Processes	Abatement Level		
	3	2	1
2911 Ferroalloy			
. Exothermic	$ .18	$ .19	$ .19
2912 Steel Foundries			
. Coke Plants			
- Charging	UC	$14.9	$17.5
- Pushing	$14.9	$17.5	$10.2
- Quenching	UC	UC	UC
- Flue Stacks	UC	$13.2	$16.2
. Blast & Open Hearth Furnace			
- Melting	$ 4.7	$ 4.7	$ 4.7
- Heating	UC	UC	UC
- Dekishing	$ 4.7	$ 4.7	$ 4.7
- Desulphuring	$ 4.7	$ 6.0	$ 7.0
- Fugitive Emissions	$13.6	431.5	$10.2
. Basic Oxygen Furnace			
- Charging	$14.7	$14.7	$16.3
- Tapping	$ 1.8	$ 1.8	$ 1.8
- Transfer	$ 1.8	$ 1.8	$ 1.8
- Melting & Refining	$ 5.4	$ 5.4	$ 5.4
- Fugitive Emissions	$13.6	$31.5	$10.2
2919 Other Primary Steel			
. Electric Arc	$ .4	$ .4	$ .4
. Boilers Scarfing & Pits	$ 0.34	$ 0.34	$ 3.4

Table 7.4C

Abatement Costs

Iron & Steel Industry

(Millions of 1986 $'s)

Sectors	Existing Annual Operating	Capital	Scenario A Annual Operating	Capital	Scenario B Annual Operating	Capital	Scenario C Annual Operating	Capital	Scenario D Annual Operating	Capital	Scenario E Phase 1 Annual Operating	Capital	Scenario E Phase 2 Annual Operating
Ferro-alloy [2911]	$0.20	$0.50	$0.20	$0.50	$0.20	$0.50	$0.20	$0.50	$0.20	$0.50	$0.20	$0.00	$0.20
Steel Foundries [2912]	$52.70	$446.10	$106.00	$446.10	$106.00	$357.00	$147.70	$446.10	$106.00	$446.10	$106.00	$0.00	$106.00
Other Primary St [2919]	$0.40	$5.00	$3.80	$5.00	$3.80	$3.80	$0.70	$5.00	$3.80	$5.00	$3.80	$0.00	$3.80
Total	$53.30	$451.60	$110.00	$451.60	$110.00	$361.30	$148.60	$451.60	$110.00	$451.60	$110.00	$0.00	$110.00

TABLE 7.4D

IRON AND STEEL INDUSTRY ANNUAL EMISSIONS GENERATED UNDER ALTERNATIVE ABATEMENT SCENARIOS AT RATED CAPACITY

(tonnes/year)

Alternative Abatement Scenarios	S.I.C. Code		Emissions Particulates
Existing	2911		19
	2912		8,823
	2919	EAF	307
		Boilers	254
A	2911		.3
	2912		4,170
	2919	EAF	140
		Boilers	63
B	2911		.3
	2912		4,170
	2919	EAF	140
		Boilers	63
C	2911		.3
	2912		6,759
	2919	EAF	281
		Boilers	190
D	2911		.3
	2912		4,170
	2919	EAF	140
		Boilers	63
E	2911		.3
	2912		4,170
	2919	EAF	140
		Boilers	63

Note:

EAF - Electric Arc Furnace

TABLE 7.5A

FOUNDRIES
CAPITAL COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

SIC Code & Manufacturing Process	Abatement Level		
	3	2	1
2941 Iron Foundries	$9.1	$55.2	$57.4
2971 Copper and Brass Works	$1.8	$11.8	$11.8
2999 Rolled Casting			
. Copper	$1.8	$ 6.2	$ 8.3
. Aluminum	$8.4	$28.4	$37.8
Sub-Total (2999)	$10.2	$34.6	$46.1

TABLE 7.5B

FOUNDRIES

ANNUAL OPERATING COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

SIC Code & Manufacturing Process	Abatement Level		
	3	2	1
2941 Iron Foundries	$17.2	$16.5	$15.3
2971 Copper and Brass Works	$ 5.2	$ 5.2	$ 6.3
2999 Rolled Casting			
. Copper	$ 4.7	$ 4.3	$ 4.3
. Aluminum	$21.3	$19.6	$19.6
Sub-Total (2999)	$26	$23.9	$23.9

Table 7.5C

Abatement Costs
Foundries
(Millions of 1986 $'s)

Sectors	Existing Annual Operating	Capital	Scenario A Annual Operating	Capital	Scenario B Annual Operating	Capital	Scenario C Annual Operating	Capital	Scenario D Annual Operating	Capital	Scenario E Phase 1 Annual Operating	Capital	Scenario E Phase 2 Annual Operating
Iron [2941]	$15.8	$57.4	$15.3	$57.4	$15.3	$55.2	$16.5	$57.4	$15.3	$57.4	$15.3	$0.0	$15.3
Copper & Brass [2971]	$3.8	$11.8	$6.2	$11.8	$6.2	$11.8	$5.2	$11.8	$6.2	$11.8	$6.2	$0.0	$6.2
Rolled Casting [2999]	$13.0	$46.1	$23.9	$46.1	$23.9	$34.6	$23.9	$46.1	$23.9	$46.1	$23.9	$0.0	$23.9
Total	$32.6	$115.3	$45.4	$115.3	$45.4	$101.6	$45.6	$115.3	$45.4	$115.3	$45.4	$0.0	$45.4

TABLE 7.5D

FOUNDRIES
ANNUAL EMISSIONS GENERATED UNDER ALTERNATIVE ABATEMENT SCENARIOS AT RATED CAPACITY

(tonnes)

Alternative Abatement Scenarios		Emissions	
		Particulates	VOCs
Existing	2941	11,406	
	2971	306	
	2999	278	3
A	2941	1,267	
	2971	55	
	2999	16	2
B	2941	1,267	
	2971	55	
	2999	16	2
C	2941	2,535	
	2971	110	
	2999	80	2
D	2941	1,267	
	2971	55	
	2999	16	2
E	2941	1,267	2
	2971	55	
	2999	16	

TABLE 7.6A

NON-FERROUS SMELTERS AND REFINERIES CAPITAL COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

Plant Types	SIC Code	Additional Control Systems	Abatement Level 3	Abatement Level 2	Abatement Level 1
Primary Smelters	2959	Baghouse	--	$ 74.8	$159.0
		Cyclones	$ 1.4	$ 1.4	$ 1.4
		ESPs	$121.4	$ 8.0	$ .8
		Scrubbers	$ 1.2	$ 1.6	$ 1.6
		Quench Towers	--	$ 14.2	$ 14.2
		Total	$124.0	$100.0	$177.0
Lead Smelters			--	--	--

Note:

Retrofit Factor is 2.

TABLE 7.6B

NON-FERROUS SMELTERS AND REFINERIES ANNUAL OPERATING COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

Plant Type	SIC Code	Abatement Level 3	Abatement Level 2	Abatement Level 1
Primary Smelters	2959	$2.0	$2.7	$2.9
Lead Smelters		- No change from existing		

Note:

Existing operating costs are not available. Figures set out represent annual operating costs for new equipment only.

Table 7.6C

Abatement Costs
Non-Ferrous Smelters & Refineries
(Millions of 1986 $'s)

												Scenario E		Scenario E
Sectors	Existing		Scenario A		Scenario B		Scenario C		Scenario D		Phase 1		Phase 2
	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating
Primary Smelters [2959]	$2.9	$177.0	$2.9	$177.0	$2.9	$100.0	$2.7	$117.0	$2.9	$117.0	$2.9	$0.0	$2.9
Lead Smelters [2959]	$0.3	$0.0	$0.3	$0.0	$0.3	$0.0	$0.3	$0.0	$0.3	$0.0	$0.3	$0.0	$0.3
Total	$3.2	$177.0	$3.2	$177.0	$3.2	$100.0	$3.0	$117.0	$3.2	$117.0	$3.2	$0.0	$3.2

TABLE 7.6D

NON-FERROUS SMELTERS AND REFINERIES
TOTAL EMISSIONS GENERATED UNDER ALTERNATIVE ABATEMENT SCENARIOS AT RATED CAPACITY

Alternative Abatement Scenarios	SIC Code	Emission (tonnes/yr)						
		Particulate	Arsenic	Copper	Iron	Lead	Nickel	Zinc
Existing	2959	15,432	133	709	1,898	214	495	30
A	2959	1,026	9	47	127	14	35	2
B	2959	1,026	9	47	127	14	35	2
C	2959	2,060	15	96	251	30	67	7
D	2959	1,026	9	47	127	14	35	2
7 E	2959	1,026	9	47	127	14	35	2

Table 7.7A

AUTOMOTIVE INDUSTRY
CAPITAL COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY
($000,000)

SIC Code and Manufacturing Processes	Abatement Level 3	Abatement Level 2	Abatement Level 1
3231 - automobile and light duty truck surface coating	$ 94.8	$111.0	$1,483.1
3254 - steering and suspension	--	--	$ 16.9
3255 - brake lining production	--	--	$ 2.4
- aluminum wheel production	--	--	--
3259 - wet cell automotive battery production	$ 4.2	$ 5.9	$ 8.3

Note:

1) Costs are in 1986 dollars.

Table 7.7B

AUTOMOTIVE INDUSTRY
ANNUAL OPERATING COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY
($000,000)

SIC Code and Manufacturing Processes	Abatement Level 3	Abatement Level 2	Abatement Level 1
3231 - automobile and light duty truck surface coating	$13.14	$16.0	$ 8.0
3254 - steering and suspension	$ 8.7	$ 8.7	$ 8.7
3255 - brake lining production	$ 1.23	$ 1.23	$ 1.23
- aluminum wheel production	$ 0.27	$ 0.27	$ 0.27
3259 - wet cell automotive battery production	$ 2.1	$ 2.1	$ 2.1

Note:

1) Costs are in 1986 dollars.

Table 7.7C

Abatement Costs
Automotive Industry
(Millions of 1986 $'s)

Sectors	Existing	Scenario A		Scenario B		Scenario C		Scenario D		Scenario E Phase 1		Scenario E Phase 2	
	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating
Auto Surface Coating [3231]	$0.0	$111.0	$16.0	$1,483.1	$8.0	$94.8	$13.1	$0.0	$111.0	$0.0	$0.0	$111.0	$16.0
Steering & Suspension [3254]	$8.7	$0.0	$8.7	$16.9	$8.7	$0.0	$8.7	$0.0	$8.7	$0.0	$8.7	$0.0	$8.7
Brake Lining [3255]	$1.2	$0.0	$1.2	$2.4	$1.2	$0.0	$1.2	$0.0	$1.2	$0.0	$1.2	$0.0	$1.2
Aluminium Wheel [3255]	$0.3	$0.0	$0.3	$0.0	$0.3	$0.0	$0.3	$0.0	$0.3	$0.0	$0.3	$0.0	$0.3
Wet Cell Auto Battery [3259]	$2.1	$8.3	$2.1	$8.3	$2.1	$5.9	$2.1	$8.3	$2.1	$8.3	$2.1	$0.0	$2.1
Total	$12.3	$119.3	$28.3	$1,510.7	$20.3	$100.7	$25.4	$8.3	$123.3	$8.3	$12.3	$111.0	$28.3

Table 7.7D

AUTOMOTIVE INDUSTRY ANNUAL EMISSIONS GENERATED UNDER ALTERNATIVE ABATEMENT SCENARIOS AT RATED CAPACITY

Alternative Abatement Scenarios		Emissions (tonnes/year)				
			Particulates			
		VOC	Lead	Asbestos	Talc	Others
Existing	3231	25,730				
	3254					41
	3255			.1	19	.3
	3259		51			
A	3231	12,541				
	3254					41
	3255			.02	19	
	3259		3			.1
B	3231	11,676				
	3254					4
	3255			.1	19	.1
	3259		3			
C	3231	17,946				
	3254					41
	3255			.1	19	.3
	3259		5			
D	3231	12,541				
	3254					41
	3255			.1	19	.1
	3259		3			
E	3231	12,541				
	3254					41
	3255			.1	19	.1
	3259		3			

TABLE 7.8A

INORGANIC CHEMICAL MANUFACTURING INDUSTRY CAPITAL COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

SIC Code & Manufacturing Processes	Abatement Level 3	Abatement Level 2	Abatement Level 1
3511 Domestic Clay	$ 8.7	$24.1	$24.1
3512 Imported Clay	--	--	--
3521 Cement	--	$17.1	$46.7
3571 Abrasives	--	$ .6	$ 2.1
3581 Lime	--	$ 1.5	$ 4.5
3711 General Inorganic Chemicals	--	$79.0	$108.0
3721 Chemical Fertilizer	$ .2	$ .2	$ 1.8
	$ 8.9	$122.5	$187.2

TABLE 7.8B

INORGANIC CHEMICAL MANUFACTURING INDUSTRY ANNUAL OPERATING COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

SIC Code & Manufacturing Processes	Existing	Abatement Level 3	Abatement Level 2	Abatement Level 1
3511 Domestic Clay	$ 2.9	$ 2.9	$ 3.8	$ 3.8
3512 Imported Clay	$ .1	$ .1	$ .1	$ .1
3521 Cement	$ 3.8	$ 3.8	$ 4.2	$ 4.7
3571 Abrasives	$ .3	$ .3	$ .3	$ .3
3581 Lime	$ .4	$ .4	$ .5	$ .5
3711 General Inorganic Chemicals	$15.6	$15.6	$19.4	$21.5
3721 Chemical Fertilizer	$ .2	$ .2	$ .2	$ .2
	$23.2	$23.2	$28.4	$31.0

Table 7.8C

Abatement Costs
Inorganic Chemical Manufacturing Industry
(Millions of 1986 $'s)

Sectors	Existing Annual Operating	Capital	Scenario A Annual Operating	Capital	Scenario B Annual Operating	Capital	Scenario C Annual Operating	Capital	Scenario D Annual Operating	Capital	Scenario E Phase 1 Annual Operating	Capital	Scenario E Phase 2 Annual Operating
Domestic Clay [3511]	2.9	24.1	3.8	24.1	3.8	24.1	3.8	$24.1	$3.8	$24.1	$3.8	$0.0	$3.8
Imported Clay [3512]	0.1	0	0.1	0	0.1	0	0.1	$0.0	$0.1	$0.0	$0.1	$0.0	$0.1
Cement [3521]	3.6	46.7	4.7	46.7	4.7	17.1	4.2	$46.7	$4.7	$46.7	$4.7	$0.0	$4.7
Abrasives [3571]	0.1	2.1	0.4	2.1	0.4	0.6	0.4	$2.1	$0.4	$2.1	$0.4	$0.0	$0.4
Lime [3581]	0.3	4.5	0.6	4.5	0.6	1.5	0.6	$4.5	$0.6	$4.5	$0.6	$0.0	$0.6
General Inorganic [3711]	15.6	108	21.5	108	21.5	79	19.4	$108.0	$21.5	$108.0	$21.5	$0.0	$21.5
Fertilizer [3721]	0.2	1.8	0.2	1.8	0.2	0.2	0.2	$1.8	$0.2	$1.8	$0.2	$0.0	$0.2
Total	$22.8	$187.2	$31.3	$187.2	$31.3	$122.5	$28.7	$187.2	$31.3	$187.2	$31.3	$0.0	$31.3

TABLE 7.8D

INORGANIC CHEMICAL MANUFACTURING INDUSTRY ANNUAL EMISSIONS GENERATED UNDER ALTERNATIVE ABATEMENT SCENARIOS AT RATED CAPACITY

Abatement Scenarios		Emissions (tonnes/yr)				
		Part.	VOCs	SO_2	F	NO_x
Existing	3511	392	701	876	637	112
	3512	1,945				
	3521	6,633		23,184		25,515
	3571	917		3,667		
	3581	3,334				
	3711	5,009	4846	1,081	29	2,028
	3721	2				
Total Existing		18,232		28,808		
A	3511	89	350	446	14	112
	3512	389				
	3521	1,268		11,813		25,515
	3571	235		186		
	3781	954				
	3711	582	49	50		727
	3721	.1				
Total Scenario A		3,517		12,495		
B	3511	89	350	446	14	64
	3512	389				
	3521	1,268		11,813		25,515
	3571	235		186		
	3581	954				
	3711	582	49	50		727
	3721	.1				
Total Scenario B		3,517		12,495		
C	3511	257	350	446	159	112
	3512	1,945				
	3521	1,748		11,813		25,515
	3571	235		367		
	3581	2,274	4846			
	3711	2,368		141	9	1,238
	3721	.7				
Total Scenario C		8,828		12,767		
D	3511	89	350	446	14	112
	3512	389				
	3521	1,268		11,813		25,515
	3571	235		186		
	3581	954				727
	3711	582	49	50	1	
	3721	.1				
Total Scenario D		3,517		12,495		
E	3511	89	350	446	14	112
	3512	1,945				
	3521	1,268		11,813		25,515
	3571	235		186		
	3581	954				
	3711	582	49	50	1	727
	3721	.1				
Total Scenario E		5,073		12,495		

TABLE 7.9A

PETROLEUM REFINING

CAPITAL COSTS FOR EQUIPMENT

REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

(SIC 3611)

($000,000)

	Abatement Level		
Processes	3	2	1
Process Combustion & Boilers	$9.0	$40.0	$79.4
Catalytic Cracking	$50.4	$116.3	$116.3
Sulphur Plant	--	$ 15.4	$ 15.4
Storage Tanks	--	$26.3	$26.3
Pumps and Compressors	--	--	--

TABLE 7.9B

PETROLEUM REFINING
ANNUAL OPERATING COSTS FOR EQUIPMENT AND PERSONNEL REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

(SIC 3611)

($000,000)

	Abatement Level		
Processes	3	2	1
Process Combustion & Boilers	$ 2.7	$ 10.0	$ 19.4
Catalytic Cracking	$ 2.8	$ 10.8	$ 25.9
Sulphur Plant	--	$ .009	$ .009
Storage Tanks	--	$ (.3)	$ (.3)
Pumps and Compressors	$ 8.4	$ 8.4	$ 21.0

Table 7.9C

Petroleum Refineries Abatement Costs (Millions of 1986 $'s)

Sectors	Existing	Scenario A		Scenario B		Scenario C		Scenario D		Scenario E Phase 1		Scenario E Phase 2	
	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating
Petroleum Refineries [3611]	$13.3	$237.4	$53.4	$237.4	$66.0	$156.3	$29.2	$237.4	$53.4	$195.7	$45.3	$41.7	$53.4

TABLE 7.9D

PETROLEUM REFINING
ANNUAL EMISSIONS GENERATED UNDER ALTERNATIVE ABATEMENT SCENARIOS AT RATED CAPACITY
(SIC 3611)

(tonnes/yr)

Alternative Abatement Scenarios	Emissions (tonnes)			
	SO_2	NO_x	PM	VOCs
Existing	42,784	7,861	4,608	2,695
A	22,568	4,804	1,083	2,019
B	13,967	3,657	1,083	1,785
C	42,287	4,804	1,442	2,501
D	22,568	4,804	1,083	2,019
E	42,784	7,861	4,608	2,695

TABLE 7.10A

ASPHALT PAVING INDUSTRY
CAPITAL COSTS FOR EQUIPMENT REQUIRED
TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

Plant Type	Existing Control System	Abatement Level 3	Abatement Level 2	Abatement Level 1
Permanent	Baghouse	--	--	--
Portable	Venturi P15	$5.4	$7.4	$7.4
	Baghouse	--	--	--

TABLE 7.10B

ASPHALT PAVING INDUSTRY
ANNUAL OPERATING COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

(SIC 3699)

($000,000)

Plant	Abatement Level		
Type	3	2	1
Permanent	14.5	14.5	14.5
Portable	3.1	2.6	2.6
	.5	.5	.5

Table 7.10C

Abatement Costs
Asphalt Paving Industry
(Millions of 1986 $'s)

											Scenario E		Scenario E
Sectors	Existing		Scenario A		Scenario B		Scenario C		Scenario D		Phase 1		Phase 2
	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating
Asphalt [3699]	$17.8	$7.4	$17.6	$7.4	$17.6	$5.4	$18.1	$7.4	$17.6	$7.4	$17.6	$0.0	$17.6

TABLE 7.10D

ASPHALT PAVING INDUSTRY
ANNUAL EMISSIONS GENERATED UNDER ALTERNATIVE ABATEMENT SCENARIOS AT RATED CAPACITY
(SIC 3699)

(tonnes/yr)

Alternative Abatement Scenarios	Particulate
Existing	1,089
A	843
B	843
C	966
D	843
E	843

TABLE 7.11A

PETROCHEMICAL PRODUCTS INDUSTRY
CAPITAL COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

SIC Code & Manufacturing Process	Abatement Level		
	3	2	1
3712 Organic Chemical Industry	$420	$588	$840
3731 Plastics and Synthetic Resins	$ 22.1	$ 22.1	$ 22.1
3751 Paint & Varnish	--	$ 1.6	$ 1.8
3791 Printing Ink	$ 8.0	$ 10.4	$ 16.7
3792 Adhesives	--	9.6	9.6
3799 Other Chemicals	$ 50.0	$ 60.0	$ 71.0
9721 Dry Cleaning	$ --	$ 97.9	$ 97.9

TABLE 7.11B

PETROCHEMICAL PRODUCTS INDUSTRY
ANNUAL OPERATING COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

SIC Code & Manufacturing Process	Abatement Level			
	Existing	3	2	1
3712 Organic Chemical Industry	$42.0	$42.0	$58.8	$84.0
3731 Plastics and Synthetic Resins	$ 2.2	$ 2.2	$ 2.2	$ 2.2
3751 Paint & Varnish	$ 1.1	$ 1.1	$ .2	$ .2
3791 Printing Ink	$ .8	$ .8	$ 1.0	$ .2
3792 Adhesives	$ 2.0	$ 5.0	$ .8	$ .8
3799 Other Chemicals	$ 5.0	$ 5.0	$ 6.0	$ 7.0
9721 Dry Cleaning	$ 2.2	$ 3.2	$12.0	$12.0

Table 7.11C

Abatement Costs
Petro-Chemical Products
(Millions of 1986 $'s)

Sectors	Existing	Scenario A		Scenario B		Scenario C		Scenario D		Scenario E Phase 1		Scenario E Phase 2	
	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating
Organic Chemical [3712]	$42.0	$840.0	$84.0	$840.0	$84.0	$588.0	$58.8	$840.0	$84.0	$500.0	$50.0	$340.0	$84.0
Plastics & Synthetic Resins [3731]	$2.2	$22.1	$2.2	$22.1	$2.2	$22.1	$2.2	$22.1	$2.2	$0.0	$0.7	$22.1	$2.2
Paint & Varnish [3751]	$0.1	$1.8	$0.2	$1.8	$0.2	$1.6	$0.2	$1.8	$0.2	$1.8	$0.2	$0.0	$0.2
Printing Ink [3791]	$0.8	$16.7	$0.2	$16.7	$0.2	$10.4	$1.0	$16.7	$0.2	$12.0	$0.1	$4.7	$0.2
Adhesives [3792]	$2.0	$9.6	$0.8	$9.6	$0.8	$0.0	$2.0	$9.6	$0.8	$0.0	$0.2	$9.6	$0.8
Other Chemicals [3799]	$5.0	$71.0	$7.0	$71.0	$7.0	$60.0	$6.0	$71.0	$7.0	$49.0	$5.0	$22.0	$7.0
Dry Cleaning [9721]	$2.2	$97.9	$12.0	$97.9	$12.0	$97.9	$3.2	$97.9	$12.0	$0.0	$2.2	$97.9	$12.0
Total	$54.3	$1,059.1	$106.4	$1,059.1	$106.4	$780.0	$73.4	$1,059.1	$106.4	$562.8	$58.4	$496.3	$106.4

TABLE 7.11D

PETROCHEMICAL PRODUCTS INDUSTRY ANNUAL EMISSIONS GENERATED UNDER ALTERNATIVE ABATEMENT SCENARIOS AT RATED CAPACITY

(tonnes/yr)

Alternative Abatement Scenarios	Emission				
	Particulates	VOC	Styrene	Lead	Perchloro-ethelyne
Existing					
3712	2,314	9,191			
3731					
3751	24	3,369	1,308		
3791		34			
3792		.4			
3799	4,012	9,700		52	
9721					50
Total Existing	6,350	22,295	1,308	52	50
A					
3712	231	1,549			
3731			.1		
3751	neg.	4			
3791		1			
3792		neg.			
3799	659	498	5.4	neg.	
9721					
Total Scenario A	890	2,052	5.5	neg.	
B					
3712	231	1,549			
3731			.1		
3751	neg.	4			
3791		neg.		5	
3792					
3799	659	498			
9721					neg.
Total Scenario B	890	2,052	.1	5	neg.
C					
3712	2,266	255			
3731			.1		
3751	.1	17			
3791		2			
3792		neg.			
3799	1,311	997		35	
9721					neg.
Total Scenario C	3,577	1,271	.1	35	neg.
D					
3712	231	1,549			
3731			.1		
3751	neg.	4			
3791		1			
3792		neg.			
3799	659	498		5	
9721					neg.
Total Scenario D	890	2,052	.1	5	neg.
E					
3712	231	1,549			
3731			.1		
3751		4			
3791	neg.	1			
3792		.4			
3799	659	498		5	
9721					neg.
Total Scenario E	890	2,052	.1	5	neg.

TABLE 7.12A

ELECTRIC POWER GENERATION

CAPITAL COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

(SIC 4911)
($000,000)

Plant Type	Abatement Level 3	Abatement Level 2	Abatement Level 1
Bituminous Fired			
. Lakeview	--	$25.8	$72.9
. Lambton	--	$23.3	$61.1
. Nanticoke	--	$52.6	$133.2
Lignite Fired			
. Thunder Bay	--	$4.7	$12.2
. Atikokan	--	$2.8	$7.8
Oil Fired			
. Lennox	--	--	--

Notes:

1. All figures quoted are in 1986 dollars.
2. Sums include cost for facility and bags.
3. Costs for 2 have been factored up by 50% to take into account additional expenses for retrofit work.
4. Costs for 1 have been factored up by 100% to take into account additional expenses for retrofit work.
5. Dashed line (--) indicates that existing equipment satisfies specified abatement level and therefore no capital expenditures will be incurred.

Table 7.12B

ELECTRIC POWER GENERATION

ANNUAL OPERATING COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

(SIC 4911)
($000,000)

Plant Type	Abatement Level 3	Abatement Level 2	Abatement Level 1
Bituminous Fired			
. Lakeview	$1.28	$1.81	$2.14
. Lambton	$1.14	$1.57	$1.9
. Nanticoke	$2.39	$3.37	$3.98
Lignite Fired			
. Thunder Bay	$ .32	$ .35	$ .54
. Atikokan	$ .14	$ .2	$ .24
Oil Fired			
. Lennox	$2.1	$2.1	$2.1

Notes:

1. Costs are in 1986 dollars.

Table 7.12C

Electric Power Generation
(Millions of 1986 $'s)

Sectors	Existing	Scenario A		Scenario B		Scenario C		Scenario D		Scenario E Phase 1		Scenario E Phase 2	
	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating
Power Generation [4911]	7.4	109.2	9.4	287.2	10.9	0	7.4	109.2	9.4	0	7.4	109.2	7.4

TABLE 7.12D

ELECTRIC POWER GENERATION ANNUAL EMISSIONS GENERATED UNDER ALTERNATIVE ABATEMENT SCENARIOS AT RATED CAPACITY

(SIC 4911)
(tonnes/yr)

Alternative Abatement Scenarios	Particulates
Existing	20,197
A	7,937
B	4,231
C	20,197
D	7,937
E (Phase 1)	20,197
E (Phase 2)	7,937

TABLE 7.13A

WASTE DISPOSAL INDUSTRY
CAPITAL COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY

($000,000)

Waste Disposal Facilities	Abatement Level 3	Abatement Level 2	Abatement Level 1
. Municipal Waste Disposal			
Transfer Stations	--	$ .65	$ .65
Landfill	$8.8	$30.2	$163.1
Multichamber Incinerator	--	$ .17	$ 9.4
Semi-suspension Incinerator	--	$ .59	$ 17.2
. Sewage Sludge			
Multihearth Incinerator	$ .74	$ 1.35	$ 14.1
Fluidized Bed Incinerator	--	--	$ 14.1
Private Waste Disposal			
Commercial & Industrial Incineration	--	$ .03	$ 8.9
. Institutional Waste Disposal			
Hospitals	$110.6	$110.6	$110.6

TABLE 7.13B

WASTE DISPOSAL INDUSTRY
ANNUAL OPERATING COSTS FOR EQUIPMENT REQUIRED TO MEET ALTERNATIVE ABATEMENT LEVELS AT RATED CAPACITY
(SIC 4999)
($000,000)

Waste Disposal Facilities	Abatement Level		
	3	2	1
. Municipal Waste Disposal			
Transfer Stations	$ .07	$ .28	$ .28
Landfill	$ 3.0	$ 5.3	$ 0.0
Multichamber Incinerator	$ .18	$ .18	$ .21
Semi-suspension Incinerator	$ .39	$ .39	$ .38
. Sewage Sludge			
Multihearth Incinerator	$ .38	$ .24	$ .29
Fluidized Bed Incinerator	$ .38	$ .38	$ .29
Private Waste Disposal			
Commercial & Industrial Incineration	$ .17	$ .17	$ .20
. Institutional Waste Disposal			
Hospitals	$10.9	$10.9	$10.9

Table 7.13C

Abatement Costs
Waste Disposal Industry
(Millions of 1986 $'s)

Sectors	Existing	Scenario A		Scenario B		Scenario C		Scenario D		Scenario E Phase 1		Scenario E Phase 2	
	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating	Capital	Annual Operating
Transfer Stations [4999]	$0.1	$0.7	$0.3	$0.7	$0.3	$0.0	$0.1	$0.7	$0.3	$0.0	$0.1	$0.7	$0.3
Landfill [4999]	$3.2	$30.2	$5.3	$162.9	$0.0	$8.8	$3.0	$30.2	$5.3	$0.0	$3.2	$30.2	$5.3
Incinerators [4999]	$0.6	$26.6	$0.6	$26.6	$0.6	$0.8	$0.6	$26.6	$0.6	$26.6	$0.6	$0.0	$0.6
Sewage Sludge Incinerators [4999]	$0.6	$28.2	$0.6	$28.2	$0.6	$1.4	$0.6	$28.2	$0.6	$28.2	$0.6	$0.0	$0.6
Private Incinerators [4999]	$0.2	$8.9	$0.2	$8.9	$0.2	$0.0	$0.2	$8.9	$0.2	$8.9	$0.2	$0.0	$0.2
Hospital Incinerators [4999]	$10.9	$110.6	$10.9	$110.6	$10.9	$110.6	$10.9	$110.6	$10.9	$110.6	$10.9	$0.0	$10.9
Total	$15.6	$205.2	$17.9	$337.9	$12.6	$121.6	$15.4	$205.2	$17.9	$174.3	$15.6	$30.9	$17.9

TABLE 7.13D

THE WASTE DIPOSAL INDUSTRY

	PM	Organic Acids	NO_x	CH_4	ROG	SO_2	HCl	Pb	Hg	Cd	Cr	PCDD	PCDF	PCB	Adehydes
Existing	966	71	1326	5199	54	649	650	3.5	.4	2.6	.7	$1.2x10^{-3}$	$2.0x10^{-3}$	.5	46.6
A	658	.4	537	106	.8	220	161	2.5	.4	1.6	.6	$1.2x10^{-3}$	$2.0x10^{-3}$	.2	.2
B	658	.4	537	106	.8	220	161	2.5	.4	1.6	.6	$1.2x10^{-3}$	$2.0x10^{-3}$	.2	.2
C	658	.7	780	159	3.2	227	187	2.5	.4	2.6	.7	$1.2x10^{-3}$	$2.0x10^{-3}$	.5	.5
D	658	.4	537	106	.8	220	161	2.5	.4	1.7	.6	$1.2x10^{-3}$	$2.0x10^{-3}$	.2	.2
E	658	.4	537	106	.8	220	161	2.5	.4	1.7	.6	-	-	.2	.2

8.0 SUMMARY

8.1 Introduction

Estimates have been made of the technology likely to be required and the associated costs incurred in revising the current Regulation 308 to a proposed regulation that replaces the existing point of impingement standards with new technology-based emission limits. Three levels of abatement have been evaluated and these have been applied to five scenarios suggested by Ministry personnel for the purposes of this study. The sector and scenario costs for the proposed change are discussed in the following section.

8.2 Summary of Costs

The estimated capital and operating costs by sector for each of the five scenarios detailed in Table 2.2 are presented in Table 8.1 and are in 1986 Canadian dollars. Scenario B has the highest estimated aggregate capital cost, $4.7 billion, whereas Scenario C has the lowest cost, estimated to be $2 billion.

The degree of contaminant reduction is in inverse proportion to the above aggregate costs with Scenario C providing the lowest emission reductions and Scenario B the highest.

Capital costs would be incurred over the duration of the phase-in period (i.e. up to five years for Scenarios A, B, C and D, and up to 25 years for Scenario E) and operating costs would be incurred anually.

Scenarios A, D, and E have identical aggregate capital costs that are about a third lower than for Scenario B but fifty percent higher than for the least stringent Scenario C. Aggregate operating costs are very similar for all scenarios and range from $421 million to $457 annually.

TABLE 8.1
Scenario Abatement Costs
(Millions of 1986 $' s)

Industrial Sectors	Scenario A Costs		Scenario B Costs		Scenario C Costs	
	Capital	Operating	Capital	Operating	Capital	Operating
Open Pit Mines	$0.9	$5.4	$0.9	$5.4	$0.6	$0.6
Food Industries	$89.7	$5.2	$93.9	$5.2	$6.8	$4.9
Pulp & Paper & Allied Industry	$184.1	$21.0	$209.9	$17.5	$98.7	$15.8
Iron & Steel	$451.6	$110.0	$451.6	$110.0	$361.3	$148.6
Foundries	$115.3	$45.4	$115.3	$45.4	$101.6	$45.6
Non-ferrous Smelters	$177.0	$3.2	$177.0	$3.2	$100.0	$3.0
Automobile Industry	$119.3	$28.3	$1,510.7	$20.3	$100.7	$25.4
Inorganic Chemical Industries	$187.2	$31.3	$187.2	$31.3	$122.5	$28.7
Petroleum Refineries	$237.4	$50.7	$237.4	$63.3	$156.3	$29.2
Asphalt Paving	$7.4	$17.6	$7.4	$17.6	$5.4	$18.1
Petro-chemical Industries	$1,059.1	$111.6	$1,067.5	$111.6	$780.0	$78.6
Power Generation	$109.2	$9.4	$287.2	$10.9	$0.0	$7.4
Waste Disposal	$205.2	$17.9	$337.9	$12.6	$161.6	$15.4
	$2,943.4	$457.0	$4,683.9	$454.3	$1,995.5	$421.3

Industrial Sectors	Scenario D Costs		Scenario E Costs Phase 1		Scenario E Costs Phase 2	
	Capital	Operating	Capital	Operating	Capital	Operating
Open Pit Mines	$0.9	$5.4	$0.0	$0.3	$0.9	$5.4
Food Industries	$89.7	$5.2	$61.1	$5.0	$28.6	$5.2
Pulp & Paper & Allied Industry	$184.1	$21.0	$62.3	$10.2	$121.8	$21.0
Iron & Steel	$451.6	$110.0	$451.6	$110.0	$0.0	$110.0
Foundries	$115.3	$45.4	$115.3	$45.4	$0.0	$45.4
Non-ferrous Smelters	$177.0	$3.2	$177.0	$3.2	$0.0	$3.2
Automobile Industry	$119.3	$28.3	$8.3	$12.3	$111.0	$28.3
Inorganic Chemical Industries	$187.2	$31.3	$187.2	$31.3	$0.0	$31.3
Petroleum Refineries	$237.4	$50.7	$195.7	$45.3	$41.7	$50.7
Asphalt Paving	$7.4	$17.6	$7.4	$17.6	$0.0	$17.6
Petro-chemical Industries	$1,059.1	$111.6	$562.8	$61.7	$496.3	$111.6
Power Generation	$109.2	$9.4	$0.0	$7.4	$109.2	$9.4
Waste Disposal	$205.2	$17.9	$174.3	$15.6	$30.9	$17.9
	$2,943.4	$457.0	$2,003.0	$365.3	$940.4	$457.0

APPENDIX A

COSTING PROCEDURES

APPENDIX A - LIST OF TABLES

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A.4.5 Variable Sheet - ESP Plate Area and Costs (98% Removal Efficiency)

A.5.1 Capital Cost Equations

A.5.2 Operating Cost Equations

A.5.3 Cost Equation Parameter Definitions

APPENDIX A: COSTING PROCEDURES

A.1 Introduction

Costing algorithms used in the economic analysis of control strategies are presented in this Appendix. Basic cost equations follow those outlined by the Radian Corporation (1984), SRI International (1980), U.S. EPA (1987) and Handbook of Air Pollution Technology.

Algorithms in this Appendix are grouped according to source with those developed by the EPA used for costing both NO_x and SO_2 control strategies, those based on SRI International (1980) for NO_x control and those based on the Handbook of Air Pollution Technology (HAPT) for particulate control and incineration. All costs are converted to 1986 Canadian dollars based on Statistics Canada escalation factors.

A.2 Radian Corporation Costing Algorithms

Cost correlations developed by the Radian Corporation (1980) consist of a set of generic equations common to all control strategies and empirical relationships developed on a process by process basis. Nomenclature is common throughout all algorithms and is summarized in Table A.2.1.

Generic cost equations are outlined in Tables A.2.2 and A.2.3 and summarized algebraically in Table A.2.4. Process specific algorithms are summarized in Table A.2.5 to A.2.9 for the following control processes:

- low excess air, coal, oil and gas boilers (NO_x control)
- low excess air, pulverized coal (NO_x control)
- staged combustion (NO_x control
- sodium scrubbing flue gas desulphurization (FGD) system (SO_2 control)
- spray drying/dry scrubbing (SO_2 and particulate control)

General design specifications for FGD systems are shown in Table A.2.10.

A.3 SRI International Costing Algorithms

Costing algorithms for NO_x control by selective catalytic reduction (SCR) and selective noncatalytic reduction (SNCR) are based on data by SRI (1980). A power law correlation of the form:

$$\mathrm{COST}_1 = \mathrm{COST}_{REF} \times \left(\frac{\mathrm{capacity}_1}{\mathrm{capacity}_{REF}}\right)^{0.7}$$

was used to calculate capital and operating costs for facilities. For costing purposes, volumetric flowrate was chosen as a representative measure of capacity with a value of 1.8 million acfm calculated for the reference facility.

Cost estimates as developed by SRI for the reference facility are shown in Tables A.3.1 and A.3.2 for SCR and Table A.3.3 and A.3.4 for SNCR controls, respectively. The algorithms used for costing purposes are shown in Table A.3.5. This table also summarizes estimates of operating costs component costs according to the equation:

$$\text{component cost} = OC_1 * \frac{CC_{REF}}{OC_{REF}}$$

where

OC_1 = operating cost of facility being costed;
CC_{REF} = component cost of reference facility
OC_{REF} = operating cost of the reference facility

A.4 Handbook of Air Pollution Control (HAPT)

Costing equations and relationships contained in HAPT have been developed into a commercial programme (TK!Solver*) which was used to calculate capital and operating costs for particulate control, and incineration.

The procedure in TK!Solver* is to first select a rule sheet which defines the relationship and equations and secondly to present the input variables and calculated output variables for a number of options available for any specific air pollution control device.

* Registered Trademark

The rule sheet for Fabric Filter Costs is shown in Table A.4.1 and the Variable sheet in Table A.4.2.

The rule sheet for Electrostatic Precipitators is shown in Table A.4.3 and the companion rule sheet is shown in Tables A.4.4 and A.4.5.

A.5 Simplified Cost Equation Development

Equations for the determination of costs of abatement were first developed using the methods employed in the Handbook of Air Pollution Technology, 1984. These methods and the equations used were then compared with those described in the EAB Control Cost Manual, 1987. The techniques were similar although minor differences were found in the coefficients and the exponents used in the two references. The EAB manual dealt with a limited number of control technologies; it was therefore decided to continue using the procedures in the Handbook of Air Pollution Technology in order to maintain consistency in the techniques.

Once the equations were selected, the programmes for estimating costs were developed using a commercially developed programme. For repetitive calculations involving the control of installations of similar sizes and types, cost curves were developed permitting the costs of control to be determined using only one or two input terms. In many applications this became a necessity since details of other operating conditions were unknown and had to be assumed to be same as those of comparable installations. The equation for these cost curves are described in the following section.

Cost Equations

For repetitive calculations of control equipment costs for which there was limited input data, simplified equations were developed for both capital and operating costs. Table A.5.1 lists the capital cost equations and Table A.5.2 provides the operating cost equations. The parameters used in the equations are listed and described in Table A.5.3.

When all of the necessary input data are available the accuracy of the calculated costs are estimated to be between 20 and 30% (EAB 1987). Using cost curves the accuracy is reduced and the individual estimates are probably of the order of between 25 and 50%. These estimates should not be expected to indicate accurately the costs of any installation nor even the total costs of control of an industry. They are based not only on approximate equations, but on data which in many cases was incomplete.

Despite these cautions it is believed that the comparisons drawn between the various levels of control based on the equations can be used to draw preliminary conclusions about the relative impact should any of the options for the implementation of the proposed revision to the regulation be exercised.

References - Appendix A

Calvert, S., and Englund, H.M, ed. 1984. Handbook of Air Pollution Control Technology. John Wiley and Sons, Inc.

Radian Corporation, 1984. *Industrial Boiler SO_2 Cost Report.* Prepared for U.S. Environmental Protection Agency, EPA-450/3-85-011, November 1984.

SRI International, 1980. *Nitrogen Oxides: Reduction in Flue Gases.* Prepared for the Energy Technology Economics Program, Report No. 17, October.

U.S. Environmental Protection Agency (EPA), 1987. *EAB (Economic Analysis Branch) Control Cost Manual*, Third Edition. Research Triangle Park, EPA 450/5-87-001A.

Table A.1.1

ANNUALIZED COST EQUATION

$$CRF = \frac{i\ (1 + i)^n}{(1 + i)^n - 1}$$

$$AC = OC + CRF * CC$$

where:

AC = annualized cost

CC = capital cost

CRF = capital recovery factor

i = interest rate, assumed to be 10%

OC = yearly operating costs

n = control system life

TABLE A.2.1 NOMENCLATURE USED IN COST ALGORITHMS

1. Capital Costs (1978 dollars)

EQUP = Equipment
INST = Installation
TD = Total Direct
IND = Indirect (Engineering, Field, Construction, Start-up, and other miscellaneous costs)
TDI = Total Direct and Indirect
CONT = Contingencies
TK = Turnkey
LAND = Land
WC = Working Capital
TOTL = Total Capital

2. Operation and Maintenance Costs (1978 dollars/year)

DL = Direct Labor
SPRV = Supervision Labor
MANT = Maintenance Labor
SP = Spare Parts
ELEC = Electricity
UC = Utilities and Chemicals
WTR = Water
SW = Solid Waste Disposal
SLG = Sludge Waste Disposal
LW = Liquid Waste Disposal
SC = Sodium Carbonate
LMS = Limestone
LIME = Lime
FUEL = Fuel
TDOM = Total Direct Operation and Maintenance
OH = Overhead
TOTL = Total Operation and Maintenance

3. Annualized Costs (1978 dollars/year)

CR = Capital Recovery
WCC = Working Capital Charges
MISC = Miscellaneous (G & A, Taxes, Insurance)
TCC = Total Capital Charges
TOTL = Total Annualized Charges

TABLE A-2.1 (Continued)

4. Boiler Specifications

Q = Thermal Input (10^6 Btu/hr) (MW)[b]
FLW = Flue Gas Flowrate (acfm) (m^3/s)[b]
CF = Capacity Factor (-)[c]
BCRF = Capital Recovery Factor for Boiler System

5. Fuel Specifications

FC = Fuel Cost ($/10^6$ Btu) ($MJ)[b]
H = Heating Value (Btu/lb) (KJ/kg)[b]
S = Sulfur Content (percent by weight)
A = Ash Content (percent by weight)
N = Fuel Nitrogen Content (percent by weight)

6. SO_2 Control Specifications

UNCSO2 = Uncontrolled SO_2 Emissions (lb/10^6 Btu) (ng/J)[b]
CTRSO2 = Controlled SO_2 Emissions (lb/10^6 Btu) (ng/J)[b]
EFFSO2 = SO_2 Removal Efficiency (percent)
CRFSO2 = Capital Recovery Factor for SO_2 Control System

7. PM Control Specifications

UNCPM = Uncontrolled PM Emissions (lb/10^6 Btu) (ng/J)[b]
CTRPM = Controlled PM Emissions (lb/10^6 Btu) (ng/J)[b]
EFFPM = PM Removal Efficiency (percent)
CRFPM = Capital Recovery Factor for PM Control System

8. Cost Rates

ELEC = Electricity Rate ($/kw-hr)
WTR = Water Rate ($/$10^3$ gal) ($/$m^3$)[b]
ALIME = Lime Rate ($/ton) ($/kg)[b]
ALS = Limestone Rate ($/ton) ($/kg)[b]
SASH = Sodium Carbonate Rate ($/ton) ($/kg)[b]
SLDG = Sludge Disposal Rate ($/ton) ($/kg)[b]
SWD = Solid Waste Disposal Rate ($/ton) ($/kg)[b]
LWD = Liquid Waste Disposal Rate ($/$10^3$ gal) ($/$m^3$)[b]
DLR = Direct Labor Rate ($/man-hr)
SLR = Supervision Labor Rate ($/man-hr)
AMLR = Maintenance Labor Rate ($/man-hr)

TABLE A-2.1 (Continued)

9. Miscellaneous

S1 = Heat Specific Sulfur Removal (kg S/1000 MJ)
S2 = Time Specific Sulfur Removal (kg S/hr)
LF = Labor Factor (-)[d]

10. NO_x Control Specifications

FFAC = F-Factor (dscf/10^6 Btu)
UNCEA = Uncontrolled Excess Air (%)
CTREA = Controlled Excess Air (%)
PRCT = Percent Flame Extension Due to Staging
DELT = Change in the flue gas exit temperature due to the elimination of the air preheater or a reduction in its effectiveness.
$CRFNO_x$ = Capital Recovery Factor for NO_x Control System

---

[a] Cost categories are not mutually exclusive. For example, some costing routines include electricity and waste cost in the utilities category while other calculate these cost separately.

[b] FGD algorithms use metric units.

[c] (-) factor presented as fraction not as percent.

Table A.2.2

CAPITAL COST COMPONENTS[a]

(1) Direct Costs

Equipment
+ Installation
= Total Direct Costs

(2) Indirect Costs

Engineering (10% of total direct costs)
+ Construction and Field Expenses (10% of total direct costs)
+ Construction Fees (10% of total direct costs)
+ Start Up Costs (2% of total direct costs)
+ Performance Costs (1% of total direct costs)
= Total Indirect Costs

(3) Contingencies = 20% of (Total Indirect + Total Direct Costs)

(4) Total Turnkey Cost = Total Indirect Cost + Total Direct Cost + Contingencies

(5) Working Capital

(6) Total Capital Cost = Total Turnkey + Working Capital

Note:

[a] Boiler and each control system costed separately; factors apply to cost of boiler or control system considered; i.e., the engineering cost for the SO_2 control system is 10% of the direct cost of the SO_2 control system.

TABLE A.2.3 OPERATING AND MAINTENANCE COSTS COMPONENTS[a]

(1) Direct Operating Costs

Operating Labor
+ Supervision
+ Maintenance Labor, Replacement Parts and Supplies
+ Electricity
+ Water
+ Steam
+ Waste Disposal
  Solids (Fly ash and bottom ash)
  Sludge
  Liquid
+ Chemicals

Total Non-Fuel O&M
+ Fuel

= Total Direct Operating Costs

(2) Indirect Operating Costs (Overhead)

Payroll (30% Operating Labor)
+ Plant (26% of Operating Labor + Supervision + Maintenance Costs + Replacement Parts)

(3) Total Annual Operating and Maintenance Costs = Total Direct + Total Indirect Costs

---

[a] Boilers and control systems are costed separately; factors apply to boiler or control system being considered, (i.e., payroll overhead for FGD system is 30% of the labor requirement for the FGD system).

Table A.2.4

CALCULATIONS COMMON TO COST ALGORITHMS

1. Capital Costs

TD[a] = EQUP + INST
IND = 0.333 * TD[b]
TDI = TD + IND
CONT = 0.20 * TDI
WC[c] = 0.25 * TDOM
TK = EQUIP + INST + IND
TOTL = TK + WC

2. Operation and Maintenance Costs

FUEL = CF * Q * FC * 8760
TDO = Sum of all O&M Costs other than OH
OH = 0.30 * DL + 0.26 * (DL + SPRV + MANT + SP)
TOTL = TDOM + OH

3. Annualized Costs

CR = CRF * TK
WCC = 0.10 * WC
MISC = 0.04 * TK
TCC = CR + WCC + MISC
TOTL = TCC + TOTL O&M Costs

4. Labour Factors

LF = 1 if CF > 0.7
LF = 0.5 + 2.5 * (CF - 0.5) if 0.5 ≤ CF ≤ 0.7
LF = 0.5 if CF < 0.5

Note:

[a] FGD system cost algorithms compute TD without prior computation of EQUP and INST.

[b] Some algorithms compute IND explicitly as a function of boiler and/or control device specifications.

[c] Assumes 3 months of direct annual operating costs.

TABLE A.2.5 COST EQUATIONS FOR LOW EXCESS AIR APPLIED TO INDUSTRIAL BOILERS

Routine Code: LEA

Capital Costs:

Coal: EQUIP = 46.22(Q) + 6496
INST and IND = 21.30(Q) - 1123

Oil and Gas: EQUIP = 31.38(Q) + 3185
INST and IND = 11.37(Q) + 1161

Annual Costs:

SP[b] = 0.05 (TK)
FUEL = -.00053(FC)(Q)(CF)(FFAC)(UNCEA - CTREA)

---

[a] Algorithm assumes a flue gas temperature of 400°F and the ambient air temperature to be 77°F.

[b] Spare parts costs consist of the costs for spare parts, maintenance labor, and maintenance materials.

TABLE A.2.6 COST EQUATIONS FOR STAGED COMBUSTION AIR APPLIED TO PULVERIZED COAL-FIRED BOILERS

Routine Code: SCA

Capital Costs:

EQUIP = 65 (Q) + 13000
INST and IND = 60 (Q) + 2000

Annual Costs:

SP^a = 0.05 (TK)
ELEC = 105 (Q)(CF)
FUEL = 21.9 (FC)(Q)(CF)

---

[a] Spare parts costs consist of the costs for spare parts, maintenance labor, and maintenance materials.

TABLE A.2.7 COST EQUATIONS FOR STAGED COMBUSTION AIR APPLIED TO RESIDUAL OIL-FIRED BOILERS (fuel N >0.23 wt. percent)

($30 - 250 \times 10^6$ Btu/hr)

Routine Code: SCA

Capital Costs:

$TK = 1000 \left[(Q)(PRCT)\ 0.0536 + 2.56\ (PRCT)\right]$

where:

$PRCT = 30$; when $N > 0.5$
$PRCT = 81.1(N) - 18.7$ when $0.23 < N < 0.5$

Annual Costs:

$SP^a = 0.05\ (TK)$
$ELEC = 102\ (Q)(CF)$
$FUEL = 21.9\ (FC)(Q)(CF)$

---

[a] Spare parts costs consists of the costs for spare parts, maintenance labor, and maintenance maerials.

TABLE A.2.8 COST EQUATIONS FOR LIME SPRAY DRYING FGD SYSTEMS WITH PM REMOVAL

Routine Code: 05

Capital Costs:[b,c]

$TD = C1 + C2 + C3 + C4$

$C1 = 55{,}500\ (FLW)^{0.51}$

$C2 = 32{,}900\ (S2)^{0.40}$

$C3 = 18{,}400 + 8{,}260\ (FLW) + 6{,}420\ (FLW)^{0.50}$

$C4 = 256{,}320\ [W1 + W2]^{0.63}$

$W1 = Q * S/H * [0.626\ EFFSO2 - 79.9\ \ln\ (1-EFFSO2/100) - 10.1]$

$W2 = 3.96 \times 10^{-6} Q\ (UNCPM - CTRPM)$

$TK = 1.48\ TD - 110{,}400$ if $Q \leq 58.5$

$= 1.60\ TD$ if $Q > 58.5$

Annual Costs, $/Year

$OL = 8{,}760 * OLW * LF$

$SPRV = 1{,}314 * SPRV * LF$

$MANT = [0.08\ [55{,}500\ (FLW)^{0.51} + 32{,}900 (S2)^{0.40}] + M1 + M2] * LF$

$M1 = 834\ FLW$

$M2 = MANT * (4.04\ FLW + 1{,}086)$

$ELEC = 8{,}760\ CF * ELEC\ [6.14\ (FLW)^{0.82}]$

$WTR = 8{,}760\ CF * WTR\ [0.144\ FLW]$

$SW = 8{,}760\ CF * SWD\ [W3 + W4]$

$W3 = (Q * S/H) * [569\ EFFSO2 - 72{,}700\ \ln\ (1-EFFSO2/100) - 9{,}230]$

$W4 = 3.6 \times 10^{-3} Q\ (UNCPM - CTRPM)$

$LIME = 8{,}760\ CF * ALIME * (-48{,}500) * Q * S/H * [\ln\ (1-EFFSO2/100) + 0.127]$

---

[a] FGD algorithms use metric units as noted in Table .

[b] $S1 = S * EFFSO2 * 100/H$.

[cd] $S2 = S1 * Q * 3.6$.

TABLE A.2.9 COST EQUATIONS FOR SODIUM SCRUBBING FGD SYSTEMS[a]

Routine Code: S00[b,c]

Capital Costs:[d]

$TK_s = 39{,}900\,(FLW)^{0.585} + 1{,}370\,(S2)^{0.727}$

$TK_w = 26{,}500\,S_2^{\;0.39}$

$TK = TK_s + TK_w$

Annual Costs:

$DL = 1{,}100*DLW$

$SPRV = 165*SPRV$

$MANT = 0.08*TK$

$ELEC_s = 8{,}760*CF*ELEC\,[3.61(FLW) - 2.15]$

$ELEC_w = 8760*CF*ELEC\,[0.23(S2) + 1.32]$

$ELEC = ELEC_s + ELEC_w$

$WTR = 8760*CF*WTR\,[0.600(FLW) - 2.08]\,[0.527(S1) + 0.364]$

$SC = 8760*CF*SASH\,[3.33(S2) + 0.082]$

$LW = 8760*CF*LWD\,[0.0616(S2) + 0.298]$[e]

---

[a] All FGD algorithms are in metric units as noted in Table

[b] $S1 = S*EFFSO_2*100/H$

[c] $S2 = S1*Q*3.6$

[d] The subscript "s" denotes scrubber costs and the subscript "w" denotes wastewater costs.

[e] This equation assumes that the wastewater stream has a total dissolved solids concentration (TDS) of 5%.

TABLE A.2.10 GENERAL DESIGN SPECIFICATIONS FOR FGD SYSTEM FOR SO_2 CONTROL

Control Device	Item	Specification
Sodium Scrubbing FGD (SO_2 removal only) (SOD)	Scrubber type	Spray baffle
	Pressure drop[a]	8 in. H_2O
	L/G	40 gal/10^3 acf
	Disposal method	Oxidation and sewerage
Dry Scrubbing (spray drying, SO_2 and PM removal) (DS)	Material of construction	Carbon steel spray dryer and fabri filter (insulated)
	Reagent	Lime; with solids recycle at 2 kg recycle solids/kg fresh lime feed
	Fabric filter	Pulse jet; air-to-cloth ratio of 4 acfm/ft^2
	Pressure drop[a]	6 in. H_2O
	L/G	0.3 gal/acf
	Solids disposal	Trucked to off-site landfill

[a] All pressure drops refer to gas side pressure drop across entire control system.

TABLE A.3.1

ESTIMATED CAPITAL INVESTMENT FOR SELECTIVE CATALYTIC REDUCTION

Basis: 500-MW net grass-roots unit firing bituminous coal.
0.54 lb NO_2/million Btu before SCR treatment.

Capital Investment	Millions of 1979 Dollars
Plant facilities investment	
Reactors	9.10
Ducts, dampers, and expansion joints	1.98
Incremental FD fan cost	0.03
Incremental ID fan cost	0.91
Ammonia injection	1.26
Ammonia storage	0.81
General facilities	0.42
Paid-up royalties	0.11
Total plant facilities investment	14.62
Interest during construction*	2.15
Organization and start-up costs	0.73
Working capital	0.49
Initial catalyst	6.50
Total capital investment	24.49

---

*For nonregulated financing.

TABLE A.3.2

ESTIMATED OPERATING COSTS FOR SELECTIVE CATALYTIC REDUCTION

Basis: 500 MW net unit, 0.54 lb NO_2/million Btu before SCR treatment, 1.05 average stoichiometric ratio, 6,132 h/y.

First-Year Operating Costs (1979 dollars)	Million $/y
Raw materials	
Ammonia at $130/st	0.41
Catalyst	3.25
Maintenance materials	0.29
Total raw materials	3.95
Labor	
Operating labor	0.00
Operating labor supervision	0.00
Maintenance labor	0.22
Administrative and support labor	0.04
Payroll burden	0.09
Total labor	0.35
Electric power	0.49
Fixed costs	
G&A costs	0.29
Property taxes and insurance	0.37
Plant depreciation	0.58
Total fixed costs	1.24
Total operating costs	6.03

TABLE A.3.3

ESTIMATED CAPITAL INVESTMENT FOR
NON- SELECTIVE CATALYTIC REDUCTION

Basis: 500-MW net grass-roots unit firing bituminous coal.
0.54 lb NO_2/million Btu before SNR treatment.

Capital Investment	Millions of 1979 Dollars
Plant facilities investment	
Air compressor	2.08
Incremental ID fan cost	0.20
Ammonia storage	0.89
Double-grid injector system	1.68
General facilities	0.10
Paid-up royalties	0.05
Total plant facilities investment	5.00
Interest during construction*	0.73
Organization and start-up costs	0.25
Working capital	0.13
Total capital investment	6.11

---

*For nonregulated financing.

TABLE A.3.4

ESTIMATED OPERATING COSTS FOR SELECTIVE NON-CATALYTIC REDUCTION

Basis: 500-MW net unit, 0.54 lb NO_2/million Btu before SNR treatment, 1.2 average stoichiometric ratio, 6,132 h/y.

First-Year Operating Costs (1979 dollars)	Million $/y
Raw materials	
Ammonia at $130/st	0.48
Maintenance materials	0.10
Total raw materials	0.58
Labor	
Operating labor	0.00
Supervision	0.00
Maintenance labor	0.07
Administrative and support labor	0.02
Payroll burden	0.03
Total labor	0.12
Electric power	0.48
Fixed costs	
G&A costs	0.10
Property taxes and insurance	0.13
Plant depreciation	0.20
Total fixed costs	0.43
Total operating costs	1.61

Table A.3.5

COSTING ALGORITHM FOR SCR/SNCR

SCR

$\text{Capcst} = 24.49\text{E}6 * (Q/1{,}800{,}000)^{.7}$

$\text{Opcost} = 6.03\text{E}6 * (Q/1{,}800{,}000)^{.7}$

Totlab = Opcost * .35 / 6.03

Elpwr = Opcost * .49 / 6.03

Mtce = Opcost * .29 / 6.03

Ammcst = Opcost * .41 / 6.03

Fixcst = Opcost * 1.24 / 6.03

SNCR

$\text{Capcst} = 6.11\text{E}6 * (Q/1{,}800{,}000)^{.7}$

$\text{Cpcost} = 1.61\text{E}6 * (Q/1{,}800{,}000)^{.7}$

Totlab = Opcost * .12 / 1.61

Elpwr = Opcost * .48 / 1.61

Mtce = Opcost * .1 / 1.61

Ammcst = Opcost * .38 / 1.61

Fixcst = Opcost * .43 / 1.61

where Q = flow rate (acfm)

```
RULE SHEET
S Rule
- ----
```

A.4.1 Rule Sheet S-Rule - Fabric Filter Costs

```
  "Fabric Filter costs.                         File:-FFCOST.TK
* A = Q/V
* stecf(A) = z
* fA = 1/z
* AG = fA*A
  "Cost = Cc+Cb
  "Cost = a+b*AG
* Cintbasic = 4780+2.63*A+Cconv
* Cintss = Cintbasic+3910+1.6*A
* Cintins = Cintbasic+2900+1.2*A
* Cintsuct = Cintbasic+1970+.171*A
* Cmechbas = 9500+4.99*AG+Cconv
* Cmechss = Cmechbas+10500+2.71*AG
* Cmechins = Cmechbas+3250+2.53*AG
* Cmechsuck = Cmechbas+3230+0.357*AG
* Crev = 36600+4.28*AG+Cconv
* Crevss = Crev+16600+2.55*AG
* Crevins = Crev+16000+2.37*AG
* Crevsuck = Crev+2410+0.457*AG
* Cpulse = 7660+10.8*AG + Cconv
* Cpulss = Cpulse+2350+7.14*AG
* Cpulin = Cpulse+7010+3.42*AG
* Ccust = 145000+3.95*AG+Cconv
* CcSS = Ccust-71400+2*AG+Cconv
* Ccins = Ccust+54200+2*AG+Cconv
* CbagsDac = .5*AG
* CbagsOrlon = AG
* CbagsNyl = AG
* CbagsNomex = 1.65*AG
* Cbagsglass = .65*AG
* CbagsPolyprop = .9*AG
* CbagsCotton = .6*AG
* Fanpwr = .746 * Q * DeltaP * rog / 6356 / E
* Fancost = Fanpwr * 0.7457 * F * Elcost + 4.9452 * Fanpwr * .7475
* If Q >100000 then Cconv = 1070 + 96.7 * L
* If Q =<100000 then Cconv = 903 + 94 * L
* If A >1432 then Shkrpwr = (-6.393 + 1.045 * LN(AG)) * 24 * F
* If A =<1432 then Shkrpwr = 13.44 * F
* W = Q * TSF / 7000 / 2240 * F * 60
* Trcost = W * mlge * Cpertmi
* Shkrcost = Shkrpwr * Elcost + Shkrpwr *.7475 * 4.9452
* Labcost = (1.725 * lab + 0.75 * Eng) * Ohead * F
* OpCost = Fancost + Shkrcost + Labcost + Trcost + Dispcost
```

A.4.2 Variable Sheet - Fabric Filter Costs

```
RIABLE SHEET
 Input      Name     Output     Unit      Comment
 -----      ----     ------     ----      -------
                                          Fabric Filter Costs.
                                          Ref:- HAPT p359
                                          File:- FFCOST.TK
 6          V                   ft/min    Face velocity
 10         TSP                 gr/ft^3   Concentration of TSP in flue gas
            A        6166.6667 ft^2       Bag area
 37000      Q                   acfm      Gas flow rate
            z        .66666667            Intermediate function = stepf(A)
            fA       1.5                  Factor to allow for bags out of use
            AG       9250       ft^2      Gross cloth area
 8          DeltaP              in.water  Pressure drop (max)
 200        T                   F         Gas temperature
            rog      .78787879 lb/ft^3    Density of gas at operating temp.
 80         L                   ft        Length of conveyors
 .5         E                             Fan and motor efficiency
 1300       F                   hr/yr     Operating factor hr/year
 .0203      Elcost              $/kW.hr   Cost of electricity
 0          mlge                mi        Distance to disposal site
 1.1223     Cpertmi             $1986/ton Cost per ton-mile
 0          Dispcos             $1986/ton Cost per ton to landfill
 12.23      lab                 $1986     Labour wages /hr
 13.45      Eng                 $1986     Mtce labour cost /hr
 1.9        Ohead                         Factor for overheads

            Cost                $1986     Purchase cost
            Cc                  $1986     Compartment cost
            Cb                  $1986     Bag cost

            OpCost   79087.715 $1986      Annual operating cost

            Cintbas  44026.083 $1986      Cost of intermittent compartment
            Cintss   64641.487 $1986      -----"------ in SS
            Cintins  59439.003 $1986      -----"------ insulated
            Cintsuc  48551.945 $1986      -----"------ with suction fan

            Cmechba  95890.060 $1986      Cost of mechanically shaken
            Cmechss  149113.27 $1986      -----"------ in SS
            Cmechin  135772.86 $1986      -----"------ insulated
            Cmechsu  105664.92 $1986      -----"------ with suction fan

            Crev     126614.89 $1986      Cost of reverse air
            Crevss   186751.47 $1986      -----"------ in SS
            Crevins  183362.12 $1986      -----"------ insulated
            Crevsuc  136546.87 $1986      -----"------ with suction fan

            Cpulse   173556.96 $1986      Cost of pulse-jet
            Cpulss   275903.24 $1986      -----"------ in SS
            Cpulin   231385.34 $1986      -----"------ insulated

            Ccust    282872.72 $1986      Cost of custom designed FF
            CcSS     430003.26 $1986      --  -------"---------- in S/S
            Ccins    404265.18 $1986      -----------"------- insulated FF

            CbagsDa  6920.85    $1986     Cost of Dacron bags
            CbagsOr  13841.7    $1986     Cost of Orlon bags
```

A-4.2 cont'd

```
L          CbagsNy 13841.7   $1986     Cost of Nylon bags
L          CbagsNo 22838.805 $1986     Cost of Nomex bags
L          Cbagsgl 8997.105  $1986     Cost of Fibre-glass bags
           CbagsPo 12457.53  $1986     Cost of Polypropylene bags
           CbagsCo 8305.02   $1986     Cost of Cotton bags

           Fanpwr  54.743940 HP        Power for fan
           Shkrpwr 4095.4366 kWhr/yr   Power to operate shaker unit
           W       1840.5612 ton       Weight of collected ash
           Cconv   12604.177 $1986     Cost of screw conveyors (per foot)
           Fancost 1914.8986 $1986     cost of power for fan
           Shkrcos 147.71923 $1986     Cost of power for shaker/yr
           Trcost  0         $1986     Cost of ash transport
           Labcost 77025.098 $1986     Cost of labour and mtce
```

A.4.3 Rule Sheet S-Rule - ESP Plate Area and Costs

```
=================== RULE SHEET ==============================================
S Rule_______________________________________________________________________
 "ESP plate area and costs.                       File:- ESPCOST
 "                                                7 June 1988

 A = -Q * (LN(1 - eff)) / w                             "Deutsch equation
* If Q >100000 then Cconv = 1070 + 96.7 * L
 If Q =<100000 then Cconv = 903 + 94 * L
 Cins = 218000 + 6.77 * A + Cconv
 Cunins = 158000 + 4.5 * A + Cconv
 Cwet = Cunins * 2.25                               "range = *2 to *2.5 (approx)
 Cinst = Cins * 2.24
 Cunininst = Cunins * 2.24
 Cwetinst = Cwet * 2.24
 Labop = 1.725 * lab * Ohead
 Labmtce = .75 * eng * Ohead
 Fanpwr = 0.746 * Q * DeltaP * rog / 0.0808 / 6356 / E
 Fanelec = Fanpwr * .7457
 Fancst = Fanelec * F * Elcost + 4.9452 * Fanelec
 Chcost = 1.5E-3 * A * F * Elcost + 4.9452 * 1.5E-3 * A
 W = Q * TSP / 7000 / 2240 * F * 60
 Trcost = W * Mlge * Coertmi
 Lndfl = W * Toncst
 Opcost = (Labop + Labmtce) * F / 8 + Fancst + Chcost + Trcost + Lndfl

 inplantc = (Labop + Labmtce) * F / 8 + Fancst + Chcost
```

A.4.4 Variable Sheet - ESP Plate Area and Costs (95% Removal Efficiency)

```
=========================== VARIABLE SHEET =====================================
St Input---- Name---- Output---- Unit------ Comment----------------------------
                                             ESP plate area and costs
                                             ref:- HAPT and Wadden and Scheff
                                             File:- ESPCOST.TK
                                             Example

                                             w for non-metals use 0.27
                                             w for metals use 0.13

             A        9985.7763  ft^2        Plate area
   20000     Q                   acfm        Gas flow rate
   10        TSP                 gr.acfm     Conc'trt'n of TSP in inlet gas
   .95       eff                             ESP efficiency (fractional)
   .1        w                   ft/sec      Drift velocity (p. 334)
   .5        DeltaP              in.water    Pressure drop through ESP
   .0739     rog                 lb/ft^3     Gas density (at operating temp)
   80        L                   ft          Length of conveyor system
   12.23     lab                 $1986       Labour wages/hr
   13.45     eng                 $1986       Mtnce wages/hr
   1.9       Ohead                           Factor for overheads
   6864      F                   hr/yr       Operating factor hr/yr
   .0203     Elcost              $1986/kW.   Cost of electricity $/kw.hr
   .5        E                               Fan + motor eff'ncy (fraction)
   33.333333 Cpertmi             $1986       Cost of trnsport/t.ash/unit dstnce
   20        Mlge                mi          Distance to landfill site
   45        Toncst              $1986       Cost of landfill per ton

             Cunins   316277.6   $1986       Uninsulated cost
          -- Cins     439931.56  $1986       Insulated cost     -
             Cwet     711624.59  $1986       Cost of wet ESP
             Cuninin  708461.82  $1986       Installed cost of uninsulated ESP
             Cinst    985558.7   $1986       Installed cost of insulated ESP
             Cwetins  1594039.1  $1986       Installed cost of wet ESP

             Opcost   3791698    $1986       Operating costs

             Labop    40.083825  $1986       Labour cost/shift
             Labmtce  19.16625   $1986       Maintenance labour/shift
             Fanpwr   2.1469306  HP          Fan power required
             Fanelec  1.6009662  kW          Fan power (kW)
             Fancst   234.92449  $1986       Fan power cost
             Chcost   2197.9572  $1986       Cost of power for charging and rappin
             Cconv    12604.177  $1986       Cost of screw conveyors
             Trcost   3502040.9  $1986       Cost to transport ash to landfill
             Lndfl    236387.76  $1986       Cost of landfill
             W        5253.0612  ton/yr      Weight of collected ash

             inplant  53269.446  $1986       In plant costs
```

A.4.5 Variable Sheet - ESP Plate Area and Costs (98% Removal Efficiency)

```
=================== VARIABLE SHEET ============================================
St Input---- Name--- Output---- Unit----- Comment-----------------------------
                                          ESP plate area and costs
                                          ref:- HART and Wadden and Scheff
                                          File:- ESPCOST.TK
                                          Example

                                          w for non-metals use 0.27
                                          w for metals use 0.13

             A        15350.57  ft^2      Plate area
   20000     Q                  acfm      Gas flow rate
   10        TSP                gr.acfm   Conc'trt'n of TSP in inlet gas
   .99       eff                          ESP efficiency (fractional)
   .1        w                  ft/sec    Drift velocity (p. 334)
   .5        DeltaP             in.water  Pressure drop through ESP
   .0739     rog                lb/ft^3   Gas density (at operating temp)
   80        L                  ft        Length of conveyor system
   12.23     lab                $1986     Labour wages/hr
   13.45     eng                $1986     Mtnce wages/hr
   1.9       Ohead                        Factor for overheads
   6264      F                  hr/yr     Operating factor hr/yr
   .0203     Elcost             $1986/kW. Cost of electricity $/kw.hr
   .5        E                            Fan + motor eff'ncy (fraction)
   33.333333 Coertmi            $1986     Cost of trnsprt/t.ash/unit dstnce
   30        Mlge               mi        Distance to landfill site
   45        Toncst             $1986     Cost of landfill per ton

             Cunins   352403.05 $1986     Uninsulated cost
           — Cins     494330.3  $1986     Insulated cost      —
             Cwet     792906.86 $1986     Cost of wet ESP
             Cuninin  789382.83 $1986     Installed cost of uninsulated ESP
             Cinst    1107299.9 $1986     Installed cost of insulated ESP
             Cwetins  1776111.4 $1986     Installed cost of wet ESP

             Opcost   3792878.9 $1986     Operating costs

             Labop    40.083825 $1986     Labour cost/shift
             Labmtce  19.16625  $1986     Maintenance labour/shift
             Fanpwr   2.1469306 HP        Fan power required
            `Fanelec  1.6009662 kW        Fan power (kW)
             Fancst   234.92449 $1986     Fan power cost
             Chcost   3378.7956 $1986     Cost of power for charging and rapping
             Cconv    12604.177 $1986     Cost of screw conveyors
             Trcost   3502040.8 $1986     Cost to transport ash to landfill
             Lndfl    236387.76 $1986     Cost of landfill
             W        5253.0612 ton/yr    Weight of collected ash

             inplant  54450.284 $1986     In plant costs
```

Table A.5.1

CAPITAL COST EQUATIONS
($1986)

FABRIC FILTER

Mechanically Shaken

$$C = 595.26 \frac{Q^{.588}}{V^{.588}} \;.\; e^{24.598V/Q} \;.\; e^{3.938\mathrm{x}10^{-6}\,Q/V}$$

Reverse Air

$$C = 4363.4 \frac{Q^{.394}}{V^{.394}} \;.\; e^{18.326\,V/Q} \;.\; e^{5.343\mathrm{x}10^{-6}\,Q/V}$$

Pulse Jet

$$C = 369.8 \frac{Q^{.706}}{V^{.706}} \;.\; e^{25.634\,V/Q} \;.\; e^{2.803\mathrm{x}10^{-6}\,Q/V}$$

VENTURI SCRUBBER

$$C = 1.33 \;.\; Q^{0.969} \;.\; D^{0.393} \;.\; e^{-1.4\mathrm{x}10^{-5}\,Q/D}$$

ELECTROSTATIC PRECIPITATOR

Uninsulated

$$C = 373{,}000 - 10.1 \frac{Q}{W} \mathrm{LN}(1-\mathrm{Eff})$$

Insulated

$$C = 507{,}500 - 15.2 \frac{Q}{W} \mathrm{LN}(1-\mathrm{Eff})$$

TABLE A.5.1 (Continued)

Cyclone

$$C = 16000 + 6,306,152\ Q.^{4/3}\ D_c^{\ 8/3} + 378,872\ Q.^{2/3}\ D_c^{\ 4/3}$$

Quench Tower

$$C = 0.9553\ Q + 34,881$$

Spray Tower

$$C = 1.054\ Q + 178,072$$

Thermal Incinerator

$$C = 392057 * (0.036Q)^{-.721} {*} e^{(.0908*(LN(0.036Q))2)}$$

$$+57312*(0.165Q)^{-.44} e^{0.0672x(LN(.165Q))2)}$$

Wet Lime Injection (Spray Dryer)

$$C = 0.7886\ Q + 133,233$$

Catalytic Incinerator

90% Efficiency

$$C = 119,765\ Q_{CAT}^{\ -.44}\ EXP(0.0672(LN(.1873\ Q_{CAT}))^2$$
$$+ 5.36\ Q_{CAT}^{.968} + 248,402\ Q_{CAT}^{-.686}\ EXP\ (0.0622(LN\ Q_{CAT})^2)$$

99% Efficiency

$$C = 119,765\ Q_{CAT}^{-.44}\ EXP(0.0672 \times LN(.1873Q_{CAT})^2) + 9.9\ Q_{CAT}^{.946}$$

$$+ 248,402\ Q_{CAT}^{-.686}\ EXP(0.0622(LN\ Q_{CAT})^2)$$

Carbon Treatment

$$C = 14,964 + 236.974\ {\frac{Q_c*C_S*MW}{P_s^{.171}}}^{.481}$$

See Table A.3 for parameter definitions.

Table A.5.2

OPERATING COST EQUATIONS
($1986/YR)

FABRIC FILTER

Mechanically Shaken, Reverse Air & Pulse Jet

$$C = 62,007 \cdot V^{.126} \cdot Q^{4.87\times10^{-3}} \cdot e^{2.414\times10^{-6}\,Q/V}$$

VENTURI SCRUBBER

$$C = 9585 \cdot Q^{.183} \cdot D^{.136}$$

ELECTROSTATIC PRECIPITATORS

$$C = Q^{.9996} \cdot e^{254.9\,E/Q}$$

CYCLONES

C = approximately 8400

Notes:

See Table C for parameter definitions.

TABLE A.5.2 (Continued)

Quench Tower

$$C = 7.9427\ Q + 8649$$

Spray Tower

$$C = 7.9427\ Q + 8649$$

Thermal Incinerator (Afterburner)

$$C = 0.566\ Q + 17{,}013$$

Wet Lime Injection (Spray Dryer)

$$C = 0.0480\ QH + 0.0254\ Q + 52{,}612.2\ H$$

Catalytic Incinerator

90% Efficiency

$$C = 5.06 \times 10^{-5}\ Q_{CAT}\ H + 0.01\ Q_{CAT} + 2.025\ H + 1.413\ Q_{CAT}^{.968}$$

99% Efficiency

$$C = 5.06 \times 10^{-5}\ Q_{CAT}\ H + 0.01\ Q_{CAT} + 2.025\ H + 2.605\ Q_{CAT}^{.946}$$

Carbon Treatment

$$C = 39.75\ \frac{Q_c * C_s * MW^{.481}}{P_s^{.171}} + 24.93\ (Q_c * C_s * MW)$$

$$+ 576.96\ Q_c + 27{,}735.13$$

See Table A.3 for parameter definitions.

Table A.5.3

COST EQUATION PARAMETER DEFINITIONS

Parameter	Description	Units
Q	Gas flow rate	acfm
V	Face velocity at fabric filter	ft/min
D	Delta P across throat of venturi	in. water
W	Drift velocity of ESPs	ft/min
EFF	fractional efficiency of ESPs	
Q_1	Gas flow rate at cyclone	ft^3/hr
D_c	Particle diameter for 50% cut	ft
H	No. of hours per year of plant operation	hrs/yr
Q_{CAT}	Gas flow rate through Catalytic incinerator	scfm
Q_c	Gas Flow Rate Through Carbon Treatment	m^3/s
C_s	Concentration of solvent in gas stream (carbon treatment)	ppm
MW	Molecular weight of solvent	
P_s	Vapour pressure of solvent	mm(Hg)

APPENDIX B

SAMPLE CALCULATIONS

APPENDIX B - LIST OF TABLES

B.1 Ontario Hydro - Costs for Particulate Control Level I (BACT-EA) & Level 2 (BACT-EA)
B.2 Ontario Hydro - Costs for Particulate Control LEVEL 3 (LAER)
B.3A Variable Sheet - Fabric Filter Costs - Level 2 (BACT-EA)
B.3B Variable Sheet - Fabric Filter Costs - Level 3 (LAER)
B.3C Rule Sheet - S Rule - Fabric Filter Costs

APPENDIX B: Sample Calculations

General Procedure

1. Identify plants in industrial sectors and emissions of concern.

2. Obtain stack gas flowrate, temperature and contaminant concentration from available information.

3. Select a representative source or sources for which data is apparently the most reliable and, if possible, confirm with industry.

4. From literature such as U.S. EPA BACT/LAER clearing house publications, BACT reports by South Coast Air Quality Management District, and AP.42 (U.S. EPA), estimate flowrate or emission rate corresponding to the known production rate for the selected source(s).

5. Establish the degree of control necessary to meet the three levels of control.

6. For the sources under consideration, identify the necessary control system needed and estimate costs.

7. Assess sector costs by ratio of manpower or production capacity of the selected source(s) to the sector manpower of production.

Example - Ontario Hydro

In this case information was available about the size of the source and the annual emission rates. The data supplied by the MOE Inventory was assessed and found to indicate lower flow rates than were known to be the design and maximum of operating flow rates of Ontario Hydro's stations.

Data were obtained from reports on Hydro and by contact with staff of Hydro.

The flow rates and operating temperatures are listed in the attached tables showing "Costs for Particulate Control".

The flow rates vary, from station to station, even for similar sized units. It was therefore decided to carry out costing for the individual stations.

Since Hydro already need to dispose of fly ash collected by the electrostatic precipitators having a removal efficiency of 98%, no costs were allowed for ash disposal. The marginal increase in the amount of fly ash collected would have an insignificant impact (<2%) on the present costs.

Control Level Needed

The existing stations are fitted with electrostatic precipitators and meet the U.S. NSPS standards. The variability of the efficiency of precipitators due to variations in fuel quality and the concentrations of SO_2 in the exhaust streams and fly ash quality suggest that, for higher levels of control, fabric filters are the best method of ensuring compliance with Level 2 and Level 3 standards.

Level 2 Compliance for Lakeview Generating Station

The Lakeview Generating Station has eight units each generating about 300 megawatts.

For Level 2 control, a high face velocity (9 ft/min) using a reverse air shaken insulated baghouse has been used to represent the equipment best able to meet the requirements.

These units are generally limited to a maximum flow rate of about 100,000 acfm. It was therefore decided to assume that the installation on a 300 megawatt unit would require about 10 filters capable together of handling the flow of 1,127,500 acfm. Because of potential fan blade erosion, an induced draft (suction) fan was used in the estimates. No distinction in unit size was made for the minor differences in the units at Lakeview.

The costs developed are shown in the table. These costs were obtained using a commercially developed programme (TK!Solver*). A printout of the programme's Rule Sheet and the output

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* Registered Trademark

Variable Sheet are attached (Tables B.3A to C). Minor differences from the original data exist due to a change in the input for the factors z and fA used in the calculation. The revised factors allow a smoother transition in the factor (fA) which is a variable to allow for spare bags and sections shutdown for maintenance work. The factor decreases as the size of the unit increases.

The capital cost for each 300 MW generating unit baghouse is then ten times the cost for each 100,000 acfm compartment. A total of eighty compartments would be needed for the station.

Level 3 Compliance

For this level of control a face velocity of 3 ft/m (0.91 min) was selected. The larger size of filter required indicated that a "custom designed" insulated baghouse was desirable. Two baghouses each at 563,800 acfm capacity were costed for each 300 megawatt unit. Sixteen custom designed units are therefore needed for this station. The costs for this level of control are shown in Table B.2.

Retrofit Costs

A factor of 1.5 was selected for the installation of the smaller level 2 baghouses, but this was increased to 2 for the larger units which would be required to meet the 3 emission limits. The problems of installing the much larger compartments would be much more likely to create problems and thus likely increase the retrofit costs.

Overall Costs

In this instance it was not necessary to ratio costs from one source to determine sector costs. A simple addition is all that is needed (see Tables 12A to 12E). For the other stations, similar procedures were used to estimate costs. The major differences arise at the smaller stations Atikokan and Thunder Bay. For the former, it was assumed that two custom baghouses would be installed for the Level 3 Control. At Thunder Bay, each of the units was assumed to be controlled by a single baghouse.

TABLE B.1

ONTARIO HYDRO

Costs for Particulate Control (,000 $1986)
LEVEL 2 (BACTEA)

Generating Station	Atikoken	Lakeview	Lambton	Lennox	Nanticoke	Thunder Bay
No. of units and MCR	1 x 230	4 x 300 4 x 305	4 x 510	4 x 550	8 x 505	1 x 100 2 x 155
Total Capacity	230	2,470	2,040	2,200	4,040	410
Flue Gas Rate (scfm)	662,000	6,549,000	5,438,900	6,343,500	11,623,600	1,379,000
Exit Temp F	310	270	270	290	290	265
Flue Gas Rate (acfm)	961,774	9,020,321	7,491,315	8,976,651	16,448,491	1 x 460,090 2 x 1,163,658
Flue Gas Rate / Unit (acfm)	961,800	1,127,500	1,873,000	2,244,160	2,056,000	46,090 1,163,650
No. of Filters per Unit	8	10	18	24	20	4 10
Capital Cost per Unit	1,770	2,080	3,768	4,805	4,260	900 2,160
Capital Cost per Station	1,770	16,700	15,070	19,220	34,080	3,060
Retrofitted Cost (f=1.5)	2,655	25,050	22,605	28,830	51,120	4,590
Cost of Bags	85	790	660	780	1,450	140

TABLE B.1 (continued)

ONTARIO HYDRO (Continued)

Costs for Particulate Control (,000 $1986)
LEVEL 2 (BACTEA)

Total Capital Cost	2,745	25,840	23,260	29,610	52,570	4,732
Operating Cost per unit	200	230	390	450	420	120
Total Operating Cost	200	1,810	1,570	1,800	3,370	350

Basis:- Face velocity = 9 ft/sec (m/sec)
Capability factor = 73 %
Dacron Bags

Retrofit Factor = 1.5 to allow for some demolition and rebuilding.

TABLE B.2

ONTARIO HYDRO

Costs for Particulate Control (1,000 $1986)
LEVEL 3 (LAER)

Generating Station	Atikokan	Lakeview	Lambton	Lennox	Nanticoke	Thunder Bay
No. of units and MCR (MW)	1 x 230	4 x 300 4 x 305	4 x 510	4x 550	8 x 505	1 x 100 2 x 155
Total Capacity (MW)	230	2,420	2,040	2,200	4,040	410
Flue Gas Rate (scfm)	662,000	6,549,000	5,438,900	6,343,500	11,623,600	1,779,000
Exit Temp F	310	274	270	290	290	265
Flue Gas Rate (acfm)	961,774	9,020,221	7,491,715	8,976,651	16,448,491	460,090 2,327,316
Flue Gas Rate / Unit (acfm)	961,800	1,127,500	1,873,000	2,244,160	2,056,000	460,090 1,163,658
No. of Filters per unit	2	2	4	4	4	1 2
Capital Cost per Unit	3,500	4,076	6,830	8,110	7,460	1,680 4,200
Capital Cost per Station	3,500	32,600	27,300	32,450	59,700	5,900
Retrofitted Cost (f=2.0)	7,000	65,200	54,600	64,900	119,400	11,800
Cost of Bags	820	7,730	6,400	7,760	13,900	420

ONTARIO HYDRO (Continued)

Costs for Particulate Control (,000 $1986)
LEVEL 3 (LAER)

Total Capital Cost	7,320	72,936	61,000	72,600	133,300	12,225
Operating Cost per Station	243	2,141	1,910	2,055	3,960	543

Basis:- Face Velocity = 3 ft/min (0.914 m/sec)
Capability factor = 73 %
Nomex Bags

Retrofit Factor = 2 ; due to extra size of equipment
at low filtering velocity

TABLE B.3A

```
================ VARIABLE SHEET ==================================================
St Input---- Name--- Output--- Unit----- Comment---------------------------------
                                         Fabric Filter Costs.
                                         Ref:- HAPT p359
                                         File:- FFCOST.TK
                                         Ontario Hydro - Level 2 (BACTEA)


   9         V                 ft/min    Face velocity
   3         TSP               gr/ft^3   Concentration of TSP in flue gas
L            A       12527.778 ft^2      Bag area

L  112750    Q                 acfm      Gas flow rate

L            z       .66666667           Intermediate function = stepf(A)
L            fA      1.5                 Factor to allow for bags out of use
L            AG      18791.667 ft^2      Gross cloth area

   6         DeltaP            in.water  Pressure drop (max)
   270       T                 C         Gas temperature
             rog     .53169734 lb/ft^3   Density of gas at operating temp.
   100       L                 ft        Length of conveyors
   .5        E                           Fan and motor efficiency
   6394.8    F                 hr/yr     Operating factor hr/year
   .0203     Elcost            $/kW.hr   Cost of electricity
   0         mlge              mi        Distance to disposal site
   1.1223    Cpertmi           $1986/ton Cost per ton-mile
   0         Dispcos           $1986/ton Cost per ton to landfill
   12.23     lab               $1986     Labour wages /hr
   13.45     Eng               $1986     Mtce labour cost /hr
   1.9       Ohead                       Factor for overheads

L            Crev    192308.85 $1986     Cost of reverse air
L            Crevss  288854.71 $1986     -----"----- in SS
L            Crevins 282895.29 $1986     -----"----- insulated
L            Crevsuc 208765.94 $1986     -----"----- with suction fan
```

TABLE B.3B

```
=================== VARIABLE SHEET ====================================
St Input----- Name---- Output---- Unit------ Comment-------------------------------
                                             Fabric Filter Costs.
                                             Ref:- HAPT p359
                                             File:- FFCOST.TK
                                             Ontario Hydro - Level 3 (LAER)

   3          V                   ft/min     Face velocity
   3          TSP                 gr/ft^3    Concentration of TSP in flue gas
L             A       187933.33   ft^2       Bag area

L  563800     Q                   acfm       Gas flow rate

L             z       .95238095              Intermediate function = stepf(A)
L             fA      1.05                   Factor to allow for bags out of use
L             AG      197330      ft^2       Gross cloth area

   6          DeltaP              in.water   Pressure drop (max)
   270        T                   F          Gas temperature
              rog     .71232877   lb/ft^3    Density of gas at operating temp.
   30         L                   ft         Length of conveyors
   .5         E                              Fan and motor efficiency
   6400       F                   hr/yr      Operating factor hr/year
   .0203      Elcost              $/kW.hr    Cost of electricity
   0          mlge                mi         Distance to disposal site
   1.1223     Cpertmi             $1986/ton  Cost per ton-mile
   0          Dispcos             $1986/ton  Cost per ton to landfill
   12.23      lab                 $1986      Labour wages /hr
   13.45      Eng                 $1986      Mtce labour cost /hr
   1.9        Ohead                          Factor for overheads

L             Ccust   1359766     $1986      Cost of custom designed FF
L             CcSS    2063120.3   $1986      -----------"---------- in S/S
L             Ccins   2037382.3   $1986      -----------"------- insulated FF

L             CbagsNo 487219.61   $1986      Cost of Nomex bags

L             OpCost  133758.53   $1986      Annual operating cost
```

TABLE B.3C

```
================== RULE SHEET ==================
S Rule------------------------------------------
  "Fabric Filter costs.                    File:-FFCOST.TK
  "                                        7 June 1988


  A = Q/V
  stepf(A) = z
  fA = 1/z

  AG = fA*A

  "Cost = Cc+Cb
  "Cost = a + b * A + AG
  Cintbasic = 4780+2.63*A+Cconv
  Cintss = Cintbasic+3910+1.6*A
  Cintins = Cintbasic+2900+1.2*A
  Cintsuct = Cintbasic+1970+.171*A

  Cmechbas = 9500+4.99*AG+Cconv
  Cmechss = Cmechbas+10500+2.71*AG
  Cmechins = Cmechbas+3250+2.53*AG
  Cmechsuck = Cmechbas+3230+0.357*AG

  Crev = 36600+4.28*AG+Cconv
  Crevss = Crev+16600+2.55*AG
  Crevins = Crev+16000+2.37*AG
  Crevsuck = Crev+2410+0.457*AG

  Cpulse = 7660+10.8*AG + Cconv
  Cpulss = Cpulse+2350+7.14*AG
  Cpulin = Cpulse+7010+3.42*AG

  Ccust = 145000+3.85*AG+Cconv
  CcSS = Ccust+71400+2*AG+Cconv
  Ccins = Ccust+54200+2*AG+Cconv

  CbagsDac = .5*AG
  CbagsOrlon = AG
  CbagsNyl = AG
  CbagsNomex = 1.65*AG
  Cbagsglass = .65*AG
  CbagsPolyprop = .9*AG
  CbagsCotton = .6*AG

  rog = 1 * (460 + 82) / (460 + T)
  Fanpwr = .746 * Q * DeltaP * rog / 6356 / E
  Fancost = Fanpwr * 0.7457 * F * Elcost + 4.9452 * Fanpwr *.7457
  If Q >100000 then Cconv = 1070 + 96.7 * L
* If Q =<100000 then Cconv = 903 + 94 * L
  If A >1432 then Shkrpwr = (-6.393 + 1.045 * LN(AG)) * F
* If A =<1432 then Shkrpwr = 0.56 * F
  W = Q * TSP / 7000 / 2240 * F * 60
  Trcost = W * mlge * Cpertmi
  Shkrcost = Shkrpwr * Elcost
  Labcost = (1.725 * lab + 0.75 * Eng) / 8 * Ohead * F
  Dumpcost = Dispcost * W

  OpCost = Fancost + Shkrcost + Labcost + Trcost + Dispcost * W
```

APPENDIX C

GLOSSARY

APPENDIX C: GLOSSARY

ANNUALIZED COST	the yearly cost of a system including both direct and indirect operating costs and an amortized portion of the initial capital cost of the system
BAGHOUSE	a large chamber in which bag filters used to remove particulate from a gas stream are housed
CAPITAL RECOVERY FACTOR	a factor which when multiplied by CRF the initial capital cost yields an annualized charge which "spreads" the cost of initial investment over the life of a project
DESIGN CAPACITY	the rate at which material or energy is produced by or treated by a process when it is operated at the maximum rate for which it was designed
DRY SCRUBBING	a process in which SO_2 and other acid gases are removed from a gas stream by adsorption onto a sprayed dry or slurry sorbent, and subsequent removal of the sorbent bound SO_2 in a downstream particulate filter

FLUE GAS	gaseous products from a combustion process
FLUE GAS DESULPHURIZATION	a process by which sulphur is - FGD removed from a gas stream. The two basic methods of desulphurization are wet and dry scrubbing. Processes can be further classified as either saleable or throwaway depending upon whether sulphur compounds are recovered or discarded
FLUE GAS RECIRCULATION	a thermal NO_x reduction strategy - FGR whereby a portion of the flue gas is recirculated to the air inlet ports. The process is designed to reduce the oxygen concentration and temperature in the combustion zone
FLUIDIZED BED	an operation in which a bed of fine particles is held in suspension by an upward flowing gas stream
FLY ASH	fine noncombustible particulate matter found in combustion gases
FUEL NO_x	nitrogen dioxide produced from the reaction of fuel bound nitrogen and oxygen in the combustion gas

LIME	calcium oxide (CaO)
LIME INJECTION MODIFIED BURNER	a burner which has been redesigned to allow the direct injection of lime at the burner port of a coal fired boiler with the objective of providing a precombustion method of minimizing SO_2 generation
LIME SPRAY DRYER	a dry scrubbing process in which lime is used as the SO_2 removal agent calcium carbonate ($CaCO_3$)
LIMESTONE	calcium carbonate ($CaCO_3$)
LOW NO_x BURNER	burners designed to control the air fuel and mix in the burner area with the objective of retarding formation of fuel NO_x
MAXIMUM CONTINUOUS RATING (MCR)	the maximum rate of production power for which a power generating unit is designed when operating continuously; it is generally expressed in terms of megawatts (MW).
PROCESS	a series of actions or operations used in manufacturing something or in achieving something: e.g. in the manufacture of adipic acid or the cleaning of exhaust gases by means of a wet scrubber

RATED CAPACITY	the rate at which material or energy is produced by or treated by a process when it is operated at the maximum rate recommended by the designer or supplier of the process. This rate may be equal to or less than the design capacity. Since this rate is sometimes recorded on a plate, attached to a piece of equipment and bearing the name of the manufacturer or the supplier, it is sometimes also known as the Name-plate capacity.
SELECTIVE CATALYTIC REDUCTION - SCR	a post-combustion process in which NO_x in a gas stream is converted to nitrogen by reduction with ammonia in the presence of a catalyst. The advantage over the SNCR process is a less restrictive range on operating temperatures.
SELECTIVE NON-CATALYTIC REDUCTION - SNCR	a post combustion process in which NO_x in a gas stream is converted to nitrogen by reduction with ammonia
STAGED COMBUSTION - SCA	a NO_x reduction strategy in which a portion of combustion air is injected at the burner with the remainder introduced downstream of the burner

THERMAL NO_x	nitrogen dioxide derived from the combination of atmospheric nitrogen and oxygen during combustion processes carried out at high flame temperatures
WET SCRUBBER	a device which uses a liquid to clean a gas. In this report the term refers to a device in which SO_2 is removed from a gas stream by absorption into an alkaline solution or slurry, typically of lime or limestone

APPENDIX D

ABBREVIATIONS USED IN TABLES

ABBREVIATIONS USED IN TABLES
(Chapters 5 and 6)

Cd	cadmium
CH_4	methane
Cl_2	chlorine
ClO_2	chlorine dioxide
CO	carbon monoxide
Cr	chromium
De No_x	NO_x gas removal using ammonia
ESP	electrostatic precipitator
F	fluoride
FGR	flue gas recirculation
H_2S	hydrogen sulphide
HC	hydrocarbons
HCl	hydrochloric acid
HE	high efficiency
HF	hydrogen fluoride
Hg	mercury
ME	medium efficiency
NA	not applicable
neg.	negligible
NH_3	ammonia
NO_x	nitrogen oxides
N. acid	nitric acid
Org. Alds.	organic aldehydes
Pb	lead
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo dioxins
PCDF	polychlorinated dibenzo furans
PM	particulate matter
PVC	polyvinyl chloride
ROG	reactive organic gases
S	sulphur
SO_2	sulphur dioxide
THC	total hydrocarbon
UC	uncontrolled
VOCs	volatile organic compounds

ADDITIONAL BIBLIOGRAPHY

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Andersen, B.S. and Michael, R.S., 1982. *Continuing Compliance: A Case Study of Operation and Maintenance Procedures at Two Industrial Particulate Emissions Sources*, Journal of the Air Pollution Control Association, Vol. 32 (4), pp 419-422.

Baasel, W.D., 1988. *Capital and Operating Costs of Wet Scrubbers Installed on Coal- Fired Utilities Impacting the East Coast*, Journal of the Air Pollution Control Association, Vol. 38 (3), pp 327-332.

Bakke, E., 1980. *Application of the Lime/Limestone Flue Gas Desulfurization Process to Smelter Gases*, Journal of the Air Pollution Control Association, Vol. 30 (10), pp 1157-1161.

Braden, J.B., Babcock, L.R., Franek, W.J., 1987. *Economic Analysis of Environmental Regulations: Lessons from VC Standards for Paper Coating*, Journal of the Air Pollution Control Association, Vol. 37 (10), pp 1172-1178.

Breuer, C.T., 1984. *Retrofitting coal-fired boilers: economics for process plants*, Chemical Engineering, Vol. 91 (19), pp 97-103.

Bullin, J.A., Wilkerson, D., 1982. *NO_x Reduction in a Gas Fired Utility Boiler by Combustion Modifications*, Journal of the Air Pollution Control Association, Vol. 32 (6), pp 669-672.

Buonicore, A.J., Reynolds, J.P, Theodore, L., Farber, P.S., 1980. *Control of Fly Ash from Conventional Coal-Fired Utility Boiler*, Journal of the Air Pollution Control Association, Vol. 30 (5), pp 602-612.

Byrne, D.M., Sedman, C.B. and Pahel-Short, R.L., 1986. *Development of Federal Air Standards to Reduce Sulfur Dioxide Emissions from New Industrial Boilers,* Journal of the Air Pollution Control Association, Vol. 36 (8), pp 888-893.

Carney, K.E. and King, W.R., 1983. *Baghouse on a Glass Furnace Provides Lesson in Filter Bag Specification*, Journal of the Air Pollution Control Association, Vol. 33 (10), Pg. 1011-1014.

Carr, R.C., 1982. *Fabric Filter Technology for Coal-Fired Power Plants*, Journal of the Air Pollution Control Association, Vol. 32 (4), pp 362-366.

Carr, R.C. and Smith, W.B., 1984. *Fabric Filter Technology for Utility Coal-Fired Power Plants Part II: Application of Baghouse Technology in the Electric Utility Industry,* Journal of the Air Pollution Control Association, Vol. 31 (2), pp 178-185.

Chang, J.C. and Mobley, J.D., 1983. *Testing and Commercialization of Byproduct Dibasic Acids as Buffer Additives for Limestone Flue Gas Desulfurization Systems*, Journal of the Air Pollution Control Association, Vol. 33 (10), pp 955-962.

Chemical Engineering, 1980. *Chementator*. p. 19.

Chemical Engineering, 1982. *Chementator*. Vol. 89 (19), p.20.

Chemical Engineering, 1982. *Chementator*. Vol. 89 (19), p. 18.

Chemical Engineering, 1982. *Chementator*. Vol. 89 (20), p. 17.

Chemical Engineering, 1982. *Chementator*. Vol. 89 (20), p. 19.

Chemical Engineering, 1982. *Chementator*. Vol. 89 (25), pp 19-20.

Chemical Engineering, 1983. *Process scrubs both sulfur and nitrogen oxides*, Vol. 90 (22), pp 21-22.

Chemical Engineering, 1983. *Pollution control spending is down*, Vol. 90 (12), pp 39 & 41.

Chemical Engineering, 1983. *Chementator*. Vol. 90 (24), p. 17.

Chemical Engineering, 1984. *Chementator*. Vol. 91 (2), p. 18.

Chemical Engineering, 1984. *Chementator*. Vol. 91 (2), p. 18.

Chemical Engineering, 1984. *Chementator*. Vol. 91 (6), pp 26-27.

Chemical Engineering, 1984. *Chementator*. Vol. 91 (10), pp 18-19.

Chemical Engineering, 1984. *Chementator*. Vol. 91 (11), p. 10.

Chemical Engineering, 1984. *New systems catch both SO_x and NO_x*, Vol. 91 (12), p. 33.

Chemical Engineering, 1984. *Chementator*. Vol. 91 (13), p. 17.

Chemical Engineering, 1984. *Boom market for FGD equipment*, Vol. 91 (14), pp 36-38.

Chemical Engineering, 1984. *Urging flexibility in SO_2 controls*, Vol. 91 (15), pp 21-22.

Chemical Engineering, 1984. *A high-sulfur test centre for New York*, Vol. 91 (16), p. 29.

Chemical Engineering, 1984. *Chementator*. Vol. 91 (17), p. 20.

Chemical Engineering, 1985. *High-capacity SO_x absorbent found*, Vol. 92 (8), p. 38.

Chemical Engineering, 1985. *Chementator*. Vol. 92 (9), p. 10.

Chemical Engineering, 1985. *Chementator*. Vol. 92 (14), pp 19-20.

Chemical Engineering, 1985. *Chementator*. Vol. 92 (17), p. 9.

Chemical Engineering, 1985. *Chementator*. Vol. 92 (17), p. 11.

Chemical Engineering, 1985. *Chementator.* Vol. 93 (5), p. 12.

Chemical Engineering, 1985. *Chementator.* Vol. 92 (23), pp 18-19.

Chemical Engineering, 1986. *Chementator.* Vol. 93 (5), p. 9.

Chemical Engineering, 1986. *Chementator.* Vol. 93 (6), p. 20.

Chemical Engineering, 1986. *Chementator.* Vol. 93 (8), pp 11-12.

Chemical Engineering, 1986. *Chementator.* Vol. 93 (9), p. 20.

Chemical Engineering, 1986. *Tasks of pollution control are difficult but manageable*, Vol. 93 (9), Pg. 45.

Chemical Engineering, 1986. *Air-pollution control units*, Vol. 93 (9), p. 51.

Chemical Engineering, 1986. *Chementator.* Vol. 93 (10), pp 18-19.

Chemical Engineering, 1986. *Chementator.* Vol. 93 (14), p. 18.

Chemical Engineering, 1986. *Chementator.* Vol. 93 (14), p. 18.

Chemical Engineering, 1986. *Chementator.* Vol. 93 (18), p. 10.

Chemical Engineering, 1986. *Chementator.* Vol. 93 (21), p. 19.

Chemical Engineering, 1986. *Chementator.* Vol. 93 (22), p. 12.

Chemical Engineering, 1987. *Pollution control gets top billing in new CPI technology*, Vol. 94 (2), p. 160.

Chemical Engineering, 1987. *Solving pollution-control problems in the CPI*, Vol. 94 (11), p. 45.

Cheremisinoff, P.N., 1986. *Solvent vapor recovery and VOC emission control*, Pollution Engineering, Vol. 18 (6), pp 26-33.

Cheremisinoff, P.N., 1986. *Special report: Hazardous materials and sludge incineration*, Pollution Engineering, Vol. 18 (12), pp 32-38.

Cheremisinoff, P.N., 1987. *Update: Hazardous waste treatment*, Pollution Engineering, Vol. 19 (2), pp 42-49.

Environment Canada and J.E. Hanna Associates Inc., 1987. *Overview of the Canadian Surface Finishing Industry, Status of the Industry and Measures for Pollution Control*, Report EPS 2/S/1.

Flachsbart, P.G. and Phillips, S., 1980. *An Index and Model of Human Response to Air Quality*, Journal of the Air Pollution Control Association, Vol. 30 (7), pp 759-768.

Froelich, D.A. and Graves, G.M., 1987. *Eliminating Reheat from Existing FGD Systems, A Design and Economic Evaluation*, Journal of the Air Pollution Control Association, Vol. 37 (3), pp 314-321.

Goodwin, R.W., 1982. *Resource Recovery from Flue Gas Desulfurization Systems*, Journal of the Air Pollution Control Association, Vol. 32 (9), pp 986-991.

Greene, R., Ed., 1985. *Strong Interest Shown in Biotechnology and Pollution Control*, Chemical Engineering, Vol. 92 (5), pp 73-86.

Jaasund, S.A., 1987. *Electrostatic Precipitators: Better Wet than Dry*, Chemical Engineering, Vol. 94 (17), pp 159-163.

Jahnig, C.E. and Shaw, H., 1981. *A Comparative Assessment of Flue Gas Treatment Processes Part I - Status and Design Basis*, Journal of the Air Pollution Control Association, Vol. 31 (4), pp 421-429.

Jahnig, C.E. and Shaw, H., 1981. *A Comparative Assessment of Flue Gas Treatment Processes Part II - Environmental and Cost Comparison*, Journal of the Air Pollution Control Association, Vol. 31 (5), pp 596- 606.

Johnson, C.A., 1981. *Minnesota Power's Operating Experience with Integrated Particulate and* SO_2 *Scrubbing*, Journal of the Air Pollution Control Association, Vol. 31 (6), pp 701-705.

Johnson, C.A., Hutcheson, Romanski, J,E, and Bundy, R.P., 1980. *Operation and Maintenance Procedures for Gas Cleaning Equipment*, Selected Papers from an APCA Specialty Conference", Journal of the Air Pollution Control Association, Vol. 30 (7), pp 743-758.

Kaplan, L.J., Ass't Editor, 1982. *Chementator.* Chemical Engineering, Vol. 89 (16) pp 34-35.

Kaplan, L.J., Ass't Editor, 1982. *Cost-saving process recovers* CO_2 *from power-plant fluegas*, Chemical Engineering, Vol. 89 (24), pp 30-35.

Karlsson, H.T., Klingspor, J., Linnè, M., and Bjerle, I., 1983. *Activated Wet-Dry Scrubbing of* SO_2, Journal of the Air Pollution Control Association, Vol. 33 (1), pp 23-28.

Katari, V.S., Vatavuk, W.M. and Wehe, A.H., 1987. *Incineration Techniques for Control of Volatile Organic Compound Emissions Part II. Capital and Annual Operating Costs*, Journal of the Air Pollution Control Association, Vol. 37 (2), pp 198-201.

Komanoff, C., 1980. *Pollution Control Improvements in Coal-Fired Electric Generating Plants: What They Accomplish, What They Cost*, Journal of the Air Pollution Control Association, Vol. 30 (9), pp 1051-1057.

Lagarias, J.S., McDonald, J.R., Giovanni, D.V., 1981. *Assessment of the Commercial Potential for the High Intensity Ionizer in the Electric Utility Industry*, Journal of the Air Pollution Control Association, Vol. 31 (11), pp 1221-1228.

Lane, W.R., 1981. *Air Quality Control Equipment Guarantees*, Journal of the Air Pollution Control Association, Vol. 31 (7), pp 809-813.

Lawson, P., 1980. *Assessment of the State of the Art of Emission Control Techniques and Systems for Electric Utilities, Volume 1 - SO_2 Removal*, Ontario Hydro, Design and Development Division, January 1980, Report No. 80144.

Leckner, P., Pearson, R.O. and Wood, R.T., 1982. *Sulfuric Plant Operations: The Wellman-Lord SO_2 Recovery Process*, CEP February, pp 65-70.

Maulbetsch, J.S., McElroy, M.W. and Eskinazi, D., 1986. *Retrofit NO_x Control Options for Coal-Fired Electric Utility Power Plants*, Journal of the Air Pollution Control Association, Vol. 36 (11), pp 1294- 1298.

McBeath, I., 1987. *Status Report on Compliance with the Chlor-Alkali Mercury Regulations 1984-85*, Environment Canada, Report EPS 1/CI/1.

McIlvaine, R.W., 1982. *The Everchanging Air Pollution Control Market*, Journal of the Air Pollution Control Association, Vol. 32 (3), pp 304-309.

Norton,J.W., 1986. *Coal vs refuse for power plant combustion*, Pollution Engineering, Vol. 18 (11), p. 26.

Offen, G.R., McElroy, M.W., Muzio, L.J, 1987. *Dry Sorbent Emission Control Technologies Part II. Applications*, Journal of the Air Pollution Control Association, Vol. 37 (8), pp 968-980.

Parkinson, G., 1983. *SO_2-removal techniques ready for tighter curbs*, Chemical Engineering, Vol. 90 (15), pp 17-20.

Parkinson, G., and S. McQueen, 1984. *A shot of limestone may cure SO_2-removal woes*, Chemical Engineering, Vol. 91 (4), pp 30-35.

Piulle, W., Carr, R., and Lagomarsino, 1986. *1985 Update, Operating History and Current Status of Fabric Filters in the Utility Industry*, Journal of the Air Pollution Control Association, Vol. 36 (1), pp 100-104.

Radian Corp., 1985. *Industrial Boiler SO_2 Cost Report.* Prepared for U.S. EPA Office of Air and Radiation Office of Air Quality Planning Standards. EPA-450/3-85-011.

Remìrez, R., 1986. *Looking into cheaper ways to deal with acid rain*, Chemical Engineering, Vol. 93 (13), pp 17-19.

Remìrez, R., Hoppe, R. and McQueen, S., 1984. *Acid rain: Control, yes, but at what price?*, Chemical Engineering, Vol. 91 (10), pp 26-29.

Reynolds, J.P. and Theodore, L., 1980. *Analysis of an APCA Baghouse Operation and Maintenance Survey*, Journal of the Air Pollution Control Association, Vol. 30 (11), pp 1255-1259.

Reynolds, J., Kreidenweis, S., and Theodore, L., 1983. *Air Pollution Control Costs for Coal-to-Electricity Systems*, Journal of the Air Pollution Control Association, Vol. 33 (5), 523-531.

Ryser, J., 1983. *Incinerators for wastes: Still a heated issue*, Chemical Engineering, Vol. 90 (15), pp 20-21.

Seckington, B.R., 1980. *Assessment of the State of the Art of Emission Control Techniques and Systems for Electric Utilities, Volume 2 - NO_x*, Ontario Hydro, Design and Development Division, Report No. 80144.

Seckington, B.R., 1980. *Assessment of the State of the Art of Emission Control Techniques and Systems for Electric Utilities, Volume 4 - Fluidized Bed Combustion*, Ontario Hydro, Design and Development Division, Report No. 80144.

Seckington, B.R., 1980. *Assessment of the State of the Art of Emission Control Techniques and Systems for Electric Utilities, Volume 5 - Coal Gasification*, Ontario Hydro, Design and Development Division, Report No. 80144.

Seckington, B.R., 1980. *Assessment of the State of the Art of Emission Control Techniques and Systems for Electric Utilities, Volume 6 - Coal Liquefaction*. Ontario Hydro, Design and Development Division, Report No. 80144.

Shen, T.T., 1986. *Hazardous waste incineration: Emissions and their control*, Pollution Engineering, Vo. 18 (7), pp 50-53.

Tanzosh, F.J., 1984. *New units give boost*, Chemical Engineering, Vol. 91 (14), pp 26-29.

Turner, J.H., Viner, A.S., McKenna, J.D., Jenkins, R.E., and Vatavuk, W.M., 1987. *Sizing and Costing of Fabric Filters Part I: Sizing Considerations*, Journal of the Air Pollution Control Association, Vol. 37 (6), pp 749-759.

Turner, J.H., and Viner, A.S., Jenkins, R.E., Vatavuk, W.M. and McKenna, J.D., 1987. *Sizing and Costing of Fabric Filters Part II: Costing Considerations*, Journal of the Air Pollution Control Association, Vol. 37 (9), pp 1105-1112.

Tyler, D.D., 1982. *The BACT/LAER Clearinghouse*, Journal of the Air Pollution Control Association, Vol. 32 (11), pp 1124-1125.

Vatavuk, W.M. and Neveril, R.B., 1983. *Estimating costs of air-pollution control systems Part XIV: Costs of carbon adsorbers*, Chemical Engineering, Vol. 90 (2), pp 131- 132.

Vatavuk, W.M. and Neveril, R.B., 1983. *Estimating costs of air-pollution control systems Part XV: Costs of flares*, Chemical Engineering, Vol. 90 (4), pp 89-90.

Vatavuk, W.M. and Neveril, R.B., 1983. *Estimating costs of air-pollution control systems Part XVI: Costs of refrigeration systems*, Chemical Engineering, Vol. 90 (10) pp 95-98.

Vatavuk, W.M., and Neveril, R.B., 1984. *Estimating costs of air-pollution control systems Part XVII: Particle emissions control*, Chemical Engineering, Vol. 91 (7), pp 97-99.

Vogel, G.A. and Martin, E.J., 1983. *Hazardous Waste Incineration Part 1 Equipment sizes and integrated-facility costs*, Chemical Engineering, Vol. 90 (18), pp 143- 146.

Vogel, G.A., and Martin, E.J., 1983. *Hazardous Waste Incineration Part 2 Estimating costs of equipment and accessories*, Chemical Engineering, Vol. 90 (21), pp 75- 78.

Vogel, G.A. and Martin, E.J., 1983. *Hazardous Waste Incineration Part 3 Estimating capital costs of facility components*, Chemical Engineering, Vol. 90 (24), pp 87-90.

Vogel, G.A. and Martin, E.J., 1984. *Hazardous Waste Incineration Part 4 Estimating operating costs*, Chemical Engineering, Vol. 91 (1), pp 97-100.

Vogel, G.A. and Martin, E.J., 1984. *Hazardous Waste Incineration Part 5 Example of incinerator cost estimation*, Chemical Engineering, Vol. 91 (3), pp 121-122.

Vogel, G.A., 1985. *Air Emission Control at Hazardous Waste Management Facilities*, Journal of the Air Pollution Control Association, Vol. 35 (5), pp 558-568.

Walker, A.B. and Gawreluk, G., 1981. *ESP Performance Capability and Utilization: Past and Future*, Journal of the Air Pollution Control Association, Vol. 31 (12), pp 1303-1310.

Weismantel, G.E., Parkinson, G., Lazorko, L., Marion, L., and Shaw, J.S., 1980. *What's under the EPA bubble?*, Chemical Engineering, Vol. 87 (5), pp 77-79.

Yung-Wo, J., 1980. *Assessment of the State of the Art of Emission Control Techniques and Systems for Electric Utilities, Volume 3 - Particulate Control*, Ontario Hydro, Design and Development Division, Report No. 80144.